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BOTANICAL GAZETTE

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A CONSPECTUS OF THE GENUS LILIUM.

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(WITH FIGURES 1–14)

THE lilies have been subjects of great interest to horticulturists and botanists ever since plants have been cultivated and named. The various species come from nearly all parts of the northern hemisphere, and nearly all are markedly variable. It is to be expected that species so much collected, cultivated, selected, described, and named should present great difficulties of discrimination and a most engaging confusion of synonymy.

The genus has been monographed but once since the beginning of the binomial nomenclature. This was by Baker.[1] The American species were once monographed by Watson.[2] The former monograph was published a quarter of a century ago, and the latter twenty years ago. Since that time the number of species has been almost doubled by discoveries in California and the west, in Japan, and especially in China. Many species, formerly little known, have become widely distributed and quite familiar in cultivation. The time seems ripe to resummarize our knowledge of this great and interesting genus. While the writer is painfully conscious of many defects in the subjoined

[1] Linn. Soc. Jour. **14**: 225–251. 1874.

[2] Am. Acad. Proc. **14**: 255–258. 1879.

conspectus of species and their synonymy, he is nevertheless hopeful that those interested in the study of the genus will find it convenient at least to have the species and their names brought together.

Acknowledgments are due in particular to Mr. F. H. Horsford, whose excellent collection of lilies at Charlotte, Vermont, has been freely placed at my disposal. The accompanying illustrations are from drawings by Mr. C. W. Furlong made under my direction for Professor L. H. Bailey's *Encyclopedia of American Horticulture*. They are available for use here through the kindness of Professor Bailey and the Macmillan Company.

LILIUM *Linn.* Sp. Pl. 302. 1753.

Perianth of six distinct segments, deciduous, clawed, the claws usually distinctly grooved: stamens six, equal, slightly adhering to the ovary below; anthers attached near the middle, dehiscent along the edges: ovary sessile or nearly so, three-celled with many horizontal ovules; style clavate, more or less curved.

Succulent herbaceous plants, with scaly bulbs and leafy upright stems; leaves scattered or whorled: flowers showy, solitary, umbellate, or racemose.—Distributed through the north temperate zone.

KEY TO SPECIES.

Subgenus I. EULIRION Baker, Linn. Soc. Jour. **14**: 225. 1874. Perianth funnel-shaped, with oblanceolate segments which are recurved only at the tip: leaves linear or lanceolate, sessile or nearly so.

a. Tube scarcely widened from base to middle.
  b. Leaves linear, 1-nerved.
    c. Plant low - - - - - - - *L. Philippense* (1).
    cc. Plant tall.
      d. Flowers white, anthers yellow - - *L. Wallichianum* (2).
      dd. Flowers purplish or yellowish, anthers brown - - - - *L. sulphureum* (3).

bb. Leaves lanceolate, 3-nerved or more.
c. Stem creeping, subterranean, bulbiferous *L. Neilgherrense* (4).
cc. Stem usually erect from the bulb - *L. longiflorum* (5).
aa. Tube gradually widening from base to neck.
b. Leaves narrow lanceolate, 1-nerved, not whorled.
c. Plant dwarf.
d. Flowers white - - - - - *L. Yunnanense* (6).
dd. Flowers wine red - - - *L. Delavayi* (7).
cc. Plant medium to tall - - - - *L. Japonicum* (8).
bb. Leaves broad lanceolate, 3–7-nerved, not whorled.
c. Flowers in a spike - - - - - *L. candidum* (9).
cc. Flowers few or solitary.
d. Flowers yellow or white.
e. Pedicels bracteate.
f. Flowers white or nearly so - *L. Lowi* (10).
ff. Flowers yellowish - - - *L. primulinum* (11).
ee. Pedicels not bracteate - - - *L. Nepalense* (12).
dd. Flowers pink - - - - *L. rubellum* (13).
bbb. Leaves in whorls.
c. Flowers clear yellow - - - - *L. Parryi* (14).
cc. Flowers whitish or pinkish, spotted *L. Washingtonianum* (15).

Subgenus II. ISOLIRION Baker, Linn. Soc. Jour. **14**: 226. 1874. Flowers usually single or umbellate: perianth erect, spreading, segments recurved only in the extended flower, but not revolute; stamens diverging from the straight style.

a. Leaves more or less whorled.
b. American species, perianth segments spatulate *L. Philadelphicum* (16).
bb. Asiatic species, perianth segments lanceolate *L. medeoloides* (17).
aa. Leaves not whorled.
b. Style shorter than ovary - - - - *L. concolor* (18).
bb. Style longer than ovary.
c. Perianth segments papillose inside.
d. Leaves linear - - - - - *L. Davidi* (19).
dd. Leaves lanceolate.
e. Flowers white - - - - - *L. formosum* (20).
ee. Flowers reddish or yellowish.
f. Stem frequently bulbiferous - - *L. bulbiferum* (21).
ff. Stem not bulbiferous - - *L. croceum* (22).

cc. Perianth segments naked inside.
d. Leaves broad lanceolate, crowded - *L. elegans* (23).
dd. Leaves linear, much crowded - - *L. myriophyllum* (24).
ddd. Leaves linear, scattered.
e. American species, flowers reddish - *L. Catesbæi* (25).
ee. Asiatic species, flowers white - *L. Bakerianum* (26).

Subgenus III. ARCHILIRION Baker, Linn. Soc. Jour. **14**: 226. 1874. Perianth broadly funnelform at the base; segments finally broadly spreading, or twisted revolute from below the middle, usually prominently papillose within; stamens diverging from curved style.

a. Leaves sessile.
b. Flowers large, reddish, segments revolute - *L. tigrinum* (27).
bb. Flowers small, purplish, rotate - - - *L. oxypetalum* (28).
aa. Leaves short petiolate.
b. Flowers dull reddish.
c. Flowers few, small - - - - - *L. papilliferum* (29).
cc. Flowers many, large - - - - *L. Henryi* (30).
bb. Flowers white, yellowish, or light pink.
c. Flowers open funnelform, on rather short straight pedicels - - - - - - *L. auratum* (31).
cc. Flowers on long cernuous pedicels, segments twisted revolute - - - - - - *L. speciosum* (32).

Subgenus IV. MARTAGON Rupp. Fl. Jen. ed. Hall. 148. 1745; Baker, Linn. Soc. Jour. **14**: 226. 1874. Flowers strongly nodding, with perianth segments very revolute: stamens diverging on all sides from the curved style.

a. Leaves whorled.
b. Leaves nearly all in large whorls of 8 or more.
c. Bulb large, horizontally elongated - - - *L. puberulum* (33).
cc. Bulb small, globose.
d. European species, flowers purplish or whitish - - - - - - - - *L. Martagon* (34).
dd. Japanese species, flowers yellow, spotted - *L. maculatum* (35).
ddd. American species, flowers mostly reddish.
e. Atlantic coast species, flowers reddish-yellow, black spotted - - - - - *L. superbum* (36).
ee. Pacific coast species.
f. Perianth forming a tube - - - *L. occidentale* (37).
ff. Perianth scarcely tubular - - - *L. pardalinum* (38).

bb. Leaves in small whorls of less than 8, or partly scattered.
c. American species, flowers yellow - - - *L. parviflorum* (39).
cc. Asiatic species, flowers reddish or whitish.
d. Leaves 1-nerved - - - - - - *L. Taliense* (40).
dd. Leaves 3–5-nerved.
e. Stem puberulent, leafy throughout - - *L. Hookongense* (41).
ee. Stem glabrous, with few leaves - - *L. avenaceum* (42).

aa. Leaves not whorled.
b. Leaves lanceolate, many-nerved.
c. Perianth revolute above the middle.
d. Bulb large, ovoid; flowers yellow - - *L. monadelphum* (43).
dd. Bulb small, elongated; flowers whitish *L. polyphyllum* (44).
cc. Perianth revolute to below the middle, flowers reddish - - - - - - - - - *L. carniolicum* (45).
bb. Leaves linear, one or few-nerved.
c. Perianth segments 1.2–2.5^{cm} broad.
d. Bulb small, plant with subterranean bulbiferous stem - - - - - - - *L. Maximowiczii* (46)
dd. Bulb medium or large, globose; stem erect - - - - - - - - - *L. testaceum* (47).
cc. Perianth segments 0.6–1.2^{cm} broad.
d. Leaves crowded.
e. Perianth segments smooth inside - - *L. ochraceum* (48).
ee. Perianth segments papillose within.
f. Flowers yellow - - - - - - *L. Fargesii* (49).
ff. Flowers reddish inside.
g. Flowers whitish without, leaves very narrow - - - - - - - - *L. pomponium* (50).
gg. Flowers red outside, stem very leafy *L. Chalcedonicum* (51).
dd. Leaves scattered.
e. Style shorter than ovary - - - *L. callosum* (52).
ee. Style longer than the ovary.
f. Perianth segments usually spotted and papillose inside - - - - - - *L. Sutchuense* (53).
ff. Perianth segments smooth and unspotted inside - - - - - - - *L. tenuifolium* (54).

Subgenus V. PSEUDOMARTAGON, subgen. nov.

Inflorescence usually paniculate, with flowers tending to be erect, horizontal, or only slightly nodding at length; perianth

funnelform, with segments slightly recurved at the tip, or finally recurved from the middle.

a. Perianth narrow, segments only slightly spreading at the tip.
  b. Leaves more or less whorled.
    c. Flowers only one or two - - - - - *L. Bolanderi* (55).
    cc. Flowers usually many.
      d. Atlantic coast species - - - - *L. Grayi* (56).
      dd. Pacific coast species; bulb globose - - *L. parvum* (57)
      ddd. Pacific coast species; bulb elongated - *L. nitidum* (58).
  bb. Leaves not whorled - - - - - - *L. maritimum* (59).
aa. Perianth spreading, segments rotate spreading or somewhat recurved.
  b. Atlantic coast species; flowers yellow marked with red - - - - - - - - - *L. Canadense* (60)
  bb. Pacific coast species; flowers orange marked with red - - - - - - - - - *L. Purdyi* (61).

Subgenus VI. CARDIOCRINUM Lindl. Veg. Kingd. 205. 1847.

Perianth funnel-shaped, with oblanceolate segments, recurved only at the apex: leaves stalked, cordate-ovate.

a. Inflorescence centripetal.
  b. Lower leaves tinged with red - - - - *L. cordifolium* (62).
  bb. Lower leaves clear green - - - - - *L. giganteum* (63).
aa. Inflorescence centrifugal - - - - - *L. mirabile* (64).

1. L. PHILIPPENSE Baker, Gard. Chron. **1873**: 1141.

Bulb perennial, ovoid: stem 4.5–6^{dm} high, slender, erect: leaves 30–40, scattered, narrow linear, 7.5–10^{cm} long, 3-nerved: flowers solitary, horizontal, white, slightly tinged with green toward the base outside, 15–20^{cm} long, trumpet shaped; perianth segments oblanceolate, reflexed only at the tip, contracted into a long claw: stamens a little shorter than the perianth; pollen yellow.

Philippine islands.

2. L. WALLICHIANUM Schultes f. Syst. Veg. **8**: 1689. 1830.

L. Japonicum D. Don. (non Thunb.) Prod. Fl. Nep. 52. 1802.
L. longiflorum Wallich (non Thunb.) Tent. Fl. Nep. 40. 1826.
L. Batisua Hamilt. in Baker, Linn. Soc. Jour. **14**: 229. 1874. (*L. Batisua* Hamilt. in D. Don, Prod. Fl. Nep. 52. 1802, nomen nudum).

Bulb thick, ovoid, 5–7.5^{cm} long, with thick, acute, much imbricated scales: stem 12–18^{dm} high, stiff, horizontal at the base: leaves 50–60, scattered or crowded, sessile, ascending, the lower 15–23^{cm} long, 3-nerved, the upper shorter, wider, and often 5-nerved, and often bearing bulbils in the axils: flowers usually solitary, or sometimes two or three, horizontal or nearly so, white, tinged with green outside, fragrant; perianth segments oblanceolate-unguiculate, 18–23^{cm} long: stamens shorter than the perianth; anthers yellow: style and ovary together equaling the stamens.

Central Himalayas.

3. L. SULPHUREUM Baker, Bot. Mag. *t. 7257*. 1892.

L. Wallichianum superbum Baker, Gard. Chron. III. **10**: 480. 1891.
L. Wallichi superbum hort. in Baker, loc. cit.
L. ochroleucum The Garden (non Wallich) **40**: 338. 1891.

Bulb large, globose: stem erect, 18–20^{dm} high: leaves numerous, scattered, spreading, linear, the lower 7.5–10^{cm} long, the upper growing gradually shorter, and many of them producing bulbils in their axils: flowers usually two or three, pendant on long peduncles, fragrant, sulphur yellow, tinged outside with claret-red; perianth funnel-shaped, 18–20^{cm} long, the oblanceolate-oblong segments permanently connivent in the lower two-thirds, recurving in the upper third; outer segments but little over 2.5^{cm} broad, inner nearly 5^{cm} broad: stamens 35^{cm} shorter than the perianth segments; anthers over 25^{cm} long, with brown-red pollen: style much overtopping the anthers, curved at the apex; stigma large.

Burmah.

4. L. NEILGHERRENSE Wight, Ic. *t. 2031–2*. 1856.

L. tubiflorum Wight, Ic. *t. 2033–4*. 1856.
L. Wallichianum Wight (non Schultes), Ic. *t. 2035*. 1856.
L. Neilgherricum hort. in Lem. Illus. Hort. **10**: *t. 353*. 1863.
L. Metzii Steud. in Duch. Soc. Hort. Par. Jour. II. **4**: 556. 1870.

Bulb globose, 5–7.5^{cm} in diameter, with thick lanceolate scales; stem 3–6^{dm} high, stiff, creeping at the base: leaves 30–40,

crowded, distinctly 3–5-nerved: flowers 1–3, ascending, white, fragrant. 15–18^{cm} long, trumpet-shaped; perianth segments oblanceolate-unguiculate, reflexed only at the tip: stamens a little shorter than the perianth; pollen yellow: ovary and style as long as the stamens; capsule oblong, obtuse angled.

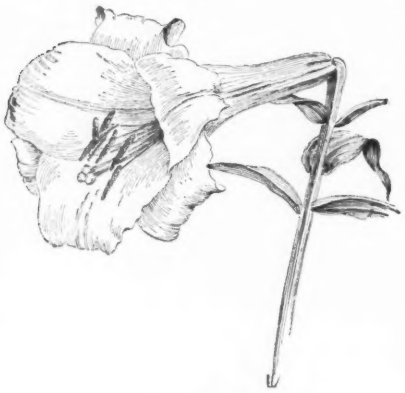


FIG. 1.—Lilium Neilgherrense.

India.

5. L. LONGIFLORUM Thunb. Linn. Soc. Trans. **2**: 333. 1794.

L. candidum Thunb. (non Linn.) Fl. Jap. 133. 1784.

L. speciosissimum hort. in Baxt. in Loud. Hort. Brit. Suppl. **2**: 645. 1830.

L. speciosum Sieb. in Verh. Batav. Gen. **12**: 15. 1830.

L. Takesima hort. in Baker, Linn. Soc. Jour. **14**: 230. 1874.

L. abchasicum hort. in Baker, loc. cit.

Bulb perennial, globose, with lanceolate scales: stem 3–9^{dm} high, erect: leaves 20–40, scattered, ascending, 5-nerved, 7.5–10^{cm} long: flowers often solitary, sometimes two or three, nearly horizontal, fragrant, waxy white; perianth narrow funnelform, segments oblanceolate, obtuse, reflexed in the upper quarter: anthers narrow, yellow, with yellow pollen: capsule narrow oblong, obtuse, angular, umbilicate.

Temperate regions of Japan, China, and Formosa. One of the best known species in cultivation.

Var. EXIMIUM Nicholson, Dict. Gard. **2**: 271. 1887.

L. eximium Comt. in Spae. Mem. Gen. Lis. 1845.

L. Jama-juri Sieb. & DeVriese, Tuinbow Fl. **1**: 319. *t. 110*. 1855.

L. eximium Wilsonii hort. Angl. in Baker, Linn. Soc. Jour. **14**: 229. 1874.

L. Harrissi hort. in Carr. Rev. Hort. **55**: 211. 1883.

Bears usually more and larger flowers on more leafy stems.

Extensively forced by florists. Sometimes called Bermuda Easter lily.

6. L. YUNNANENSE Franchet, Jour. Bot. **6**: 314. 1892.

Bulb ovate, with fleshy ovate lanceolate, sharply imbricate scales: stem slender, 3–6^{dm} high, scabrous with slender hairs, without leaves for a short distance at the base: leaves sparse, 3–5^{cm} long, narrowly lanceolate, 3-nerved, scabrous along the nerves and margins: flowers white, or on the outside slightly tinged with purple, not at all or sparingly punctate, 8–9^{cm} long solitary, or more rarely 2–3, nodding when young, later almost erect; perianth broadly open-tubular from the base, with oblong segments; nectar furrow bare: stamens half as long as the perianth; pollen yellow: style thick, a little longer than the ovary.

Yun-nan, China. "The flowers resemble *L. Japonicum* Thunb., but are smaller. Leaves like *L. elegans*."—Franchet.

7. L. DELAVAYI Franchet, Jour. Bot. **6**: 314. 1892.

Stem slender, 3–6^{dm} high, leafless below, then sparsely leaved: leaves sometimes short lanceolate, 3–4^{cm} long, at other times linear-lanceolate or linear, 3-nerved, densely and roughly papillose along the nerves and margins: flowers solitary or more rarely two or three, at first nodding, but horizontal just before full bloom, 8–9^{cm} long, wine-red, marked with crowded reddish spots; perianth for the most part broadly tubular, segments much recurved above, lower part gradually narrowed: stamens less than half the length of the perianth, with filaments smooth; pollen yellow: style twice as long as the ovary.

Yun-nan, China.

8. L. JAPONICUM Thunb. Fl. Jap. 133. 1784.

L. odorum Planch. Fl. d. Serres I. **9**: 53. 1853–4.

Bulb perennial, globose: stem 3–6^{dm} high: leaves 12–20, scattered, ascending, thin, glabrous, lanceolate, 5–7-nerved, 10–15^{cm} long: flowers often solitary, sometimes two or three, white

on the inside, tinged more or less with purple on the outside, fragrant; perianth 10–15^{cm} long, wide funnel-shaped, gradually widening; segments oblanceolate-unguiculate, obtuse, recurved in upper third: filaments less than one third the length of the perianth; pollen red: ovary with style slightly longer than the stamens; capsule obovoid, deeply and obtusely 6-angled.

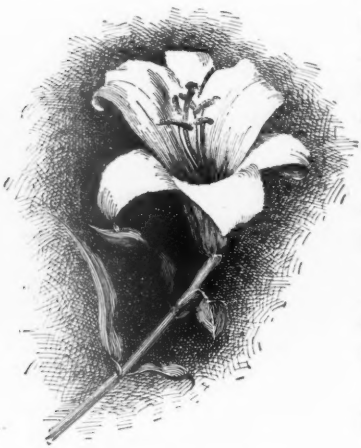


FIG. 2.—Lilium Japonicum.

Japan. Much grown in gardens, especially in its striking varieties, of which the following are the most noteworthy.

Var. BROWNII Nicholson, Dict. Gard. **2**:270. 1887.

L. Brownii Poit. Rev. Hort. II. **2**:406. 1843.

A robust, leafy, large-flowered variety, with perianth white inside and deep vinous purple outside.

Var. ROSEUM hort. in Vilm. Fl. Pl. Terre 581. 1894. [Ed. 4.]

L. Krameri hort. Teutschel in Hook. f. Bot. Mag. *t. 6058*. 1873.
L. Kramerianum Hook. f. loc. cit.
L. Krameri Barrianum Baker, Linn. Soc. Jour. **14**:231. 1874.
L. Belladona hort. Leicht in Baker, op. cit. 232. 1874.
L. Elisabethæ Leicht. in Vilm. Fl. Pl. Terre 581. 1894. [Ed. 4.]

Differs from the species in a more slender, graceful habit, and in the beautiful pale rose colored flowers.

Var. ALEXANDRÆ hort. Wallace in Baker, Gard. Chron. III. **14**:86. 1893.

L. Alexandræ hort. in Baker, loc. cit.
L. Ukeyuri hort. in Jour. Hort. 1893.

A pure white variety with longer style and broader leaves.

Uke island, Japan.

9. L. CANDIDUM Linn. Sp. Pl. 302. 1853.

L. Byzantinum Steud. Nom. **2**:44. 1840. [Ed. 2.]
L. peregrinum Mill. Dict. n. 2. [Ed. 8.]
L. candidum striatum Van Houtte, Fl. de Serr. *t. 735*.
L. candidum spicatum hort. in Baker, Linn. Soc. Jour. **14**:232. 1874.
L. candidum peregrinum Linn. in Baker, loc. cit.

Bulb ovoid, perennial large: stem leaves scattered sessile, acute bract-like above: stem 6–12^{dm} high, erect, stiff: flowers 6–25 in a raceme, 10–15^{cm} long and wide, pure white, fragrant, segments revolute in upper third, obtuse: stamens short, bearing yellow anthers: style and ovary much longer than the stamens.

Southern Europe. Several garden forms have been described as varieties of this species. Such are var. *striatum* hort., var. *spicatum* hort., and var. *peregrinum* Linn. They do not seem to be worthy of botanical rank however. One of the most ornamental species, and an old favorite, though considerably subject to disease.[3]

10. L. LOWI Baker, Bot. Mag. *t. 7232*. 1892.

L. Nepalense Coll. & Hem. (non D. Don), Linn. Soc. Jour. **28**:138. 1890.

Bulb globose, 5^{cm} in diameter, scales smal lanceolate: stem glabrous, stiffly erect, 9–12^{dm} high: leaves very numerous, scattered, sessile, linear, erecto-patent, 5–7.5^{cm} long: flowers about three, corymbose or umbellate, on long cernuous peduncles with a linear leaf at the middle; perianth open funnel-shaped, 7.5–10^{cm} long; fully expanded limb 7.5^{cm} in diameter, segments oblong-lanceolate, the inner and outer nearly uniform, white with a slight greenish tinge on the outside, white without any spots inside on the spreading upper half, tinged with yellowish green on the connivent lower half, and covered, except in the center, with minute spots of claret-brown: stamens about 2.5^{cm} shorter than the perianth; anthers large, linear, brown: stigma just overtopping the anthers.

Upper Burmah.

[3] For notes on lily disease see Vt. Exp. Sta. Rept. **11**:297. 1898.

11. L. PRIMULINUM Baker, Bot. Mag. *t.* 7227. 1892.

L. Neilgherrense Coll. & Hem. Linn. Soc. Jour. **28**:138. 1890 (non Wight).

L. Claptonense hort. Low in Baker, loc. cit. 1892.

Bulb large globose, scales lanceolate: stem stiffly erect, 9–12^{dm} high: leaves scattered, lanceolate, erecto-patent, sessile, 7.5–10^{cm} long: flowers about three, on long cernuous pedicels with a large lanceolate leaf at the middle; perianth open funnel-shaped, pale yellow, unspotted, tinted outside with green in an early state, 12–15^{cm} long; segments oblanceolate-oblong, the outer and the inner nearly uniform, above 2.5^{cm} broad at the middle, connivent in an open funnel in the lower half, subrecurved in the upper half: stamens rather shorter than the perianth; anthers linear, brown: style much overtopping the anthers, and reaching to the very tip of the perianth segments.

Upper Burmah.

12. L. NEPALENSE D. Don. Wern. Nat. Hist. Soc. Mem. **3**:412. 1820.

L. triceps Klotzsch, Bot. Ergeb. Waldem. Reise. 53. 1845.

L. nanum Klotzsch, loc. cit.

L. ochroleucum Wall. in hb. Lindl. in Baker, Linn. Soc. Jour. **14**: 231. 1874.

Stem 3–6^{dm} high, stiff: leaves 30–50, scattered, ascending, lanceolate or linear, distinctly 5–7-nerved: flowers solitary or few, slightly fragrant, nodding, yellowish white more or less tinged with purple, often with small scattered dots inside; segments oblanceolate-unguiculate, reflexed in the upper third, 10–13^{cm} long: stamen less than one fourth the length of the perianth, pollen yellow: capsule ovate, 5^{cm} long.

Temperate regions of western and central Himalayas.

13. L. RUBELLUM Baker, Gard. Chron. III. **23**: 321. 1898.

Bulb globose, with lanceolate scales: stem slender, bearing about 20 alternate, obscurely petioled, bright green, lanceolate leaves, the central ones the largest, about 5^{cm} long, conspicuously

5–7-nerved: flowers one or two, erecto-patent; perianth open funnel-shaped, pink, unspotted, nearly 7.5^{cm} long, 7.5^{cm} in diameter when fully expanded; segments oblanceolate oblong, obtuse, the inner 2.5^{cm} broad, the outer narrower, slightly tinged with green toward the base: stamens less than half as long as the perianth; anthers small, linear, bright yellow: style arcuate, overtopping the stamens.

Japan. Very recently introduced to English and American gardens. Evidently closely related to *L. Japonicum*, and doubtfully held separate from that species.

14. L. PARRYI Wats. Davenp. Acad. Proc. **2**: 188. 1886.

Bulb small with jointed scales: leaves linear-oblanceolate, usually scattered: flowers horizontal, pale yellow; segments about 7.5^{cm} long, with spreading or recurved tips: capsule narrowly oblong.

San Bernardino county, California. A pretty species, not uncommon in cultivation.

15. L. WASHINGTONIANUM Kellogg, Cal. Acad. Proc. **2**: 13. 1863.

L. Bartramii Nuttall herb. in Baker Linn. Soc. Jour. **14**: 232. 1874.

Bulb oblique, somewhat rhizomatous, with rather small, lanceolate scales: stem 6–15^{dm} high: leaves in several whorls of 5–12 each, or sometimes a few scattered, oblanceolate, spreading, sessile, 7.5–10^{cm} long: flowers few or sometimes as many as 20, on ascending pedicels, white, tinged with pink or red and dotted with purple, fragrant, rather loose funnelform; perianth segments oblanceolate, gradually narrowing downward, reflexed in the upper third: stamens short; anthers yellow: ovary less than one third the length of the curved style.

California.

Var. PURPUREUM Mast. Gard. Chron. II. **2**: 322. 1874.

L. rubescens Wats. Am. Acad. Proc. **14**: 256. 1879.

Smaller and more slender, with smaller more pinkish flowers, and perianth segments less acute.

16. L. PHILADELPHICUM Linn. Sp. Pl. 435. 1762. [Ed. 2.]

L. Pennsylvanicum Gawl. Bot. Mag. **22**: *t. 872.* 1805.
L. dauricum Gawl. Bot. Mag. **30**: sub. *t. 1210.* 1809.
L. andinum Nutt. in Fraser. Cat. 1813.
L. umbellatum Pursh. Fl. **1**: 229. 1814.
L. spectabile Link. Enum. Hort. Berol. **1**: 321. 1821.
L. verticillatum Willd. in Kunth. Enum. Pl. **4**: 263. 1843.
L. Catesbæi hort. Bouch. in Kunth. op. cit. 264. 1843.
L. Philadelphicum wansharaicum hort. in Duch. Soc. Hort. Par. Jour. II. **5**: 49. 1871.
L. montanum Nelson, Torr. Bot. Bull. **26**: 5. 1899.

FIG. 3.—Lilium Philadelphicum.

Bulb annual, rhizomatous, small, with few thick, brittle scales: stem 3–9^{dm} high, slender: leaves 10–40, lanceolate or linear, thin, glabrous, finely nerved, usually more or less whorled: flowers 1–4, terminal or umbellate, bright red, marked with large scattering purplish spots toward the center; segments 5–7.5^{cm} long, long clawed, oval above: stamens less than one third the length of the perianth; pollen red: ovary about half as long as the style; capsule narrow, obovoid.

From Canada to North Carolina and west to the Rocky mountains.

17. L. MEDEOLOIDES Gray. Am. Acad. Mem. **6**: 415. 1857.
L. Canadense Thunb.? Fl. Jap. 204. 1784.

Stem slender, 3–6^{dm} high: leaves several, often crowded into a single 7–14-foliate whorl, sometimes partly scattered, oblan-

ceolate, thin, glabrous: flowers 1–3, with short erect pedicels, open funnel-shaped, bright orange-red with a few spots within; segments lanceolate, slightly recurved from the base, thickened at the tip: ovary clavate, a little shorter than the straight style.

Japan, Korea.

18. L. CONCOLOR Salisb. Parad. Lond. *t. 47.* 1806.

Bulb perennial, ovoid, small, with few oblong, acute scales: stem slender, 3^{dm} or more high: leaves 20–30, ascending, scattered, lanceolate, $5–7.5^{cm}$ long, obscurely 7-nerved: flowers 1–3, erect; perianth $2.5–5^{cm}$ long, spreading, bright scarlet, unspotted, with segments lanceolate, thickened at the tip: pollen red: ovary clavate, deeply grooved; style clavate, very short.

China. One of the very best species for garden culture.

Var. SINICUM Hook. Bot. Mag. II. **28**: *t. 6005.* 1872.

L. Buschianum Lodd. Bot. Cab. *t. 1628.* 1825–33.
L. sinicum Lindl. in Paxt. Fl. Gard. 2, misc. 115, *t. 193.* 1851.
L. concolor Buschianum Baker, Linn. Soc. Jour. **14**: 236. 1874.

Taller, with larger bulb, flowers rather more numerous, perianth segments a little wider, bright scarlet with small black spots.

Southern Siberia.

Var. PULCHELLUM Baker, Linn. Soc. Jour. **14**: 237. 1874.

L. pulchellum Fisch. in Mey. Ind. Sem. Hort. Petrop. **6**: 56. 1839.

A slender yellow flowered variety, perhaps belonging with the next.

Var. PARTHENEION (Sieb. & DeV.) Baker, Linn. Soc. Jour. **14**: 237. 1874.

L. partheneion Sieb. & DeV., Tuinbow Fl. **2**: 341. 1855.
L. coridion Sieb. & DeV. loc. cit.

A fine yellow flowered variety, though scarcely differing from the species in any other respect.

19. L. DAVIDI Duch. in Elwes, Mon. Lil. *t. 24.* 1877.

Bulb unknown: stem erect, slender, about 8^{dm} high: leaves

60–70, crowded toward the center of the stem, linear, 10–13^{cm} long, acuminate, hardly narrowed at the base, edges revolute, one nerve at back, covered with short hairs: pedicels 5–7.5^{cm} long, with a lanceolate bract at the base, very spreading, slightly cottony at the upper end; flowers in the only known specimen 3, color apparently orange, with numerous purplish spots; perianth segments 3–3.5^{cm} long, oblong, flower wide-spreading but not revolute, with prominent papillae at the base, with a median greenish band on the outside covered with long white hairs: filaments 2.5^{cm} long, suberect; ligulate anthers 1^{cm} long; pollen yellow: style twice as long as the ovary.

Eastern Thibet.

20. L. FORMOSUM, Franchet Jour. Bot. **6**: 313. 1892.

Nearly 1^{m} high, slender: the upper leaves narrowly lanceolate, slender acuminate, three-nerved, narrowed into a short petiole: flowers one or two, erect; perianth full white, cup-shaped; segments oblong-lanceolate, 15–17^{cm} long, opening but little at the tips, obtuse, densely pubescent on the inside at the base: stamens a little shorter than the perianth, with short anthers; pollen yellow: style slender, much longer than the ovary; capsule obovate, widely truncate at the tip, 5^{cm} long.

Eastern Su-tchuen, China.

21. L. BULBIFERUM Linn. Sp. Pl. 302, ex parte. 1753.

L. humile Miller, Dict. n. 4. 1768. [Ed. 8.]
L. scabrum Moench. Meth. 305. 1794.
L. elatum Salisb. Prod. 237. 1796.
L. pubescens Bernh. in Hornem. Hort. Hafn. **2**: 962. 1807.
L. Sibericum Schlecht. Enum. Hort. Berol. Suppl. 17. 1813.
L. latifolium Link. Enum. Hort. Berol. **1**: 321. 1821.
L. purpureo-croceum Bosc. in Steud. Nom. 480. 1821. [Ed. 1.]
L. aurantiacum Sieb. in Loud. Hort. Brit. Suppl. **2**: 645. 1830.
L. lancifolium hort. Bouch. in Kunth. Enum. Pl. **4**: 364. 1843.
L. sanguineum hort. in Lindl. Bot. Reg. *t. 50*. 1846.
L. Wilsoni hort.? in T. Moore, Flor. et Pomol. 192. 1868.
L. atrosanguineum hort. in Vil. Fl. Pl. Terre, 629. 1870. [Ed. 3.]
L. biligulatum hort. in Baker, Hort. Soc. Jour. N. S. **4**: 43. 1877.
L. lateritium hort. in Baker, loc. cit.

Bulb ovoid, perennial, with a few wide acute scales: stem 6–12^{dm} high: leaves scattered, 7–5^{cm} long, the upper ones often bearing bulbils in the axils: flowers one to many, umbellate or somewhat racemose, on short stout pedicels; perianth 5–6^{cm} long, erect spreading, bright red or dark orange, usually with some dull spots, papillose toward the center.

Central Europe. Long cultivated in gardens. Many horticultural varieties have been named, but no form seems to be sufficiently marked to justify separate treatment.

22. L. CROCEUM Chaix in Vill. Hist. Pl. Dauph. **1**: 322. 1786.

L. bulbiferum DC. Fl. Fr. **3**: 202. 1805.
L. aurantiacum Dum. de Cours. Bot. Cult. **2**: 1972. 1811. [Ed. 2.]
L. aurantium Haw. in Loud. Hort. Brit. Suppl. **2**: 645. 1830.
L. pumilum hort. Bouch in Kunth. Enum. Pl. **4**: 265. 1843.

Bulb perennial, globose, with large, ovate-lanceolate scales: stem 6–15^{dm} high, vigorous: leaves numerous, crowded, linear or lanceolate, 7.5–10^{cm} long, 3–5-nerved, glabrous, never bearing bulbils in the axils: flowers solitary or 10–15 in an umbellate raceme; pedicels ascending, 5–7.5^{cm} long, white cobwebby; perianth erect, wide funnelform, 5–6^{cm} long; segments oblong-lanceolate or ovate-lanceolate, narrowed into a short claw, bright orange, conspicuously lamellar-papillose: pollen red.

Switzerland, France, northern Italy. Closely related to *L. bulbiferum*. Much cultivated, especially in Europe.

23. L. ELEGANS Thunb. Acad. St. Petersb. Mem. **3**: 203. 1811.

L. Philadelphicum Thunb. Fl. Jap. 135. 1784 (non. Linn.).
L. bulbiferum Thunb. Linn. Soc. Trans. **2**: 333. 1794 (non. Linn.).
L. Thunbergianum Schultes f. Syst. Veg. **7**: 415. 1830.
L. aurantiacum Paxt. Mag. Bot. **6**: 127. 1839.
L. atrosanguineum Sieb. in Loud. Hort. Brit. Suppl. **2**: 645. 1839.
L. fulgens Morren in Spae Mem. Gen. Lis. 29. 1845.
L. venustum Kunth, Fl. d. Serr. **7**: 33. *t.* 657. 1851.
L. sanguineum hort. in Vil. Fl. Pl. Terre 499. 1866. [Ed. 2.]
L. hæmatochroum Lemaire, Ill. Hort. **14**: *t.* 503. 1867.
L. alternans Sieb. in Duch. Soc. Hort. Par. Jour. **4**: 215. 1870.
L. umbellatum hort. in Baker, Linn. Soc. Jour. **14**: 239. 1874.
L. davuricum Gawl. in Baker, op. cit. 238.

L. aurantiacum hort. Krelage in Baker, op. cit. 239.
L. pictum hort. Sieb. in Baker, op. cit. 239.
L. Wilsoni hort. in Baker, op. cit. 240.
L. coruscans hort. in Baker, loc. cit.
L. Batmanniæ Wallace, Garden **15**: 396. 1879.

Bulb perennial, ovoid: stem 3^{dm} high or less, stiff, erect, slightly cobwebby or nearly glabrous: leaves 20–30, scattered or crowded, ascending, firm, dark green, distinctly 5–7-nerved, lanceolate: flowers 1–5, spreading funnel-shaped, usually solidly colored in some brilliant shade of yellow, orange, or red; segments spatulate, nearly smooth: capsule obovoid, 5^{cm} long.

FIG. 4.—Lilium elegans.

Japan. One of the most useful species known to the gardener. Very variable, numbering many striking garden varieties, of which the following are the most notable: var. FULGENS Baker (*L. fulgens*, *L. Batmanniæ*, and *L. sanguineum*, see above), a fine orange-red with somewhat narrowed segments; var. ATROSANGUINEUM Baker & Dyer, a very deep dark red; var. ALUTACEUM Baker & Dyer (var. *armeniacum*, var. *citrinum*, etc.), more or less clear yellow; var. BICOLOR Moore, yellow at the center and reddish outwards; var. PLENUS, nom. nov., more or less double; var. WALLACEI, comb. nov. (*L. Wallacei* Baker, *ubi?*), small, dwarf, usually one-flowered, rather pale red, perianth segments somewhat acute.

24. L. MYRIOPHYLLUM Franchet, Jour. Bot. **6**: 313. 1892.

Bulb of *L. longiflorum*: stem $1–2^{m}$ high, not rarely bearing bulbils in the axils of the leaves (and then not flowering), bare at the base, foliage crowded quite to the top of stem (leaves easily more than 200): leaves linear or lanceolate-linear, 1-nerved, very acute, with the margin revolute: flowers more often two, erect, with short peduncles, white tinged with green on the outside, full, opening cup-shaped; segments oblong, obtuse,

scarcely expanded at the tip; the nectar furrow very wide and very smooth, even to the margin: stamens a little shorter than the perianth, with short anthers and yellow pollen: style three times longer than the ovary.

Yun-nan, China. M. Franchet says of this: "Magnificent species, recalling *L. Wallichianum* Schultes by its numerous linear leaves; but easily distinguished from it by the characteristics of its rhizome, its erect flowers, and the enlarged perianth."

25. L. CATESBÆI Walt. Fl. Carol. 123. 1788.

L. Carolinianum Catesby (non Michx.) Car. **2**: *t. 58*. 1733.
L. spectabile Salisb. (non Link.) Stirp. Rar. *t. 5*. 1791.

Bulb like that of *L. Philadelphicum:* stem 3–6^{dm} high, slender, erect: leaves 20–30, scattered, lanceolate or linear-lanceolate, 5–7.5^{cm} long: flowers usually solitary, erect, wide funnel-shaped, 5–10^{cm} broad, bright orange-red marked with scattered purplish dots; perianth segments oblong-lanceolate with long attenuate tips, a grooved claw, and revolute margins: style slender, twice as long as the ovary.

North Carolina to Florida and west to Kentucky. A very pretty plant, but does not succeed in cultivation, at least not in the northern states.

26. L. BAKERIANUM Collet & Hemsley, Linn. Soc. Jour. **27**: 138. 1890.

Stems 9–12^{dm} high, two-flowered: leaves alternate, thickish, narrow linear, nerves obsolete: flowers white, erect, long pedunculate, campanulate, about 10^{cm} long and broad; segments of the perianth unequal, contiguous, slightly recurved, base broad, spotted, inner surface naked: stamens less than half the length of the perianth.

Shan hills, India, at 1200^{m} altitude. Not yet known in cultivation.

27. L. TIGRINUM Andr. Bot. Rep. **9**: errata. 1809.

L. pomponium Lour. Fl. Cochinch. 207. 1790.
L. speciosum Andr. (non Thunb). Bot. Rep. *t. 586*. 1797–1804.
L. sinense hort. in Steud. Nom. **2**: 44. 1840. [Ed. 2.]
L. Fortuni Lindl. Gard. Chron. **1862**: 212.

L. Leopoldi hort. in Baker, Linn. Soc. Jour. **14**: 233. 1874.
L. erectum Baker, loc. cit.

Bulb perennial, globose, with oblong-lanceolate, acute scales: stem 6–15^{dm} high, somewhat whitish cobwebby: leaves scattered, rich green, ascending, linear, 7.5–10^{cm} long, 5–7-nerved, the upper leaves shorter and bearing bulbils in their axils: flowers 3–10, or sometimes more, in a wide raceme, nodding, bright red, thickly spotted with large purplish spots; perianth segments lanceolate-acuminate, strongly twisted revolute, papillose on the claw: filaments scarlet, anthers black, pollen scarlet: ovary half as long as the much curved style.

FIG. 5.—Lilium Tigrinum.

Japan and China. An old-fashioned garden favorite, and one of the best lilies for general culture, especially in the var. *splendens*.

Var. SPLENDENS Leicht. in Van H. Fl. d. Serr. **17**: 130. 1868.

A fine garden variety of more robust habit than the species, with long flowering spikes.

Var. PLENESCENS, nom. nov.

An odd double variety grown in collections.

Other garden varieties are to be referred without confusion to the species.

BURLINGTON, VERMONT.

[*To be concluded.*]

SOME APPLIANCES FOR THE ELEMENTARY STUDY OF PLANT PHYSIOLOGY.

W. F. GANONG.

(WITH FIGURES 1–7.)

THE enlargement of the bounds of knowledge in any science, though primarily dependent on the researches of specialists, is greatly aided by a wide diffusion of their results through proper teaching. Thus are public sympathy and support enlisted, while the greater number of students attracted allows of wider selection and hence better material for the development of new investigators. This is all true of plant physiology, but at this particular time there is an additional reason for attention to it. Elementary botanical teaching is at present being improved to the point of reorganization, and the advance is chiefly in the direction of the study of the plant alive and at work, and of the interpretation of plant-structure through plant-function. This necessarily involves experimental plant physiology, the chief obstacles to whose wide introduction are the expense and difficulty of making it a laboratory study. The greatest service that can be rendered to the advancement of botanical teaching at the present time seems to me the invention of simpler, more manageable, less expensive and more logically conclusive experiments for demonstrating the most fundamental facts and principles of plant-physiology. This is as legitimate a subject for investigation as any other, and one whose difficulty and the ultimate scientific value of whose results give it no mean rank.

Most of the purchasable physiological appliances have been invented by investigators for obtaining results of a precise quantitative character, and are usually cumbrous, complicated, and expensive. An investigator can afford to use nothing less than the best, but in elementary teaching, where it is chiefly qualitative results that are sought, great simplification in appli-

ances should be possible. No doubt when the stimulus of a wide use in teaching shall direct the proper combination of physiological knowledge and inventive skill more extensively in this direction, astonishingly simple ways of demonstrating important facts and principles will be found. Much has already been done along this line, but every teacher knows that many of the apparently simple experiments of the books are not actually practicable, nor do they always cover the more important topics. Just here, indeed, lies the kernel of the whole matter; it is not only practicable experiments that are wanted, but experiments upon the most fundamental topics, absorption, transfer, transpiration, photosynthesis, respiration, growth, irritability. One good experiment upon such themes is worth many upon minor ones. No doubt the subject will ultimately work itself out for elementary classes in much the same way that it has already done in physics, namely, in the form of a standard series of a dozen or fifteen experiments on the leading topics, the apparatus for which will be purchasable at a fair cost from supply companies.

The appliances here to be described have been developed in the author's courses in Smith College. Every piece has been many times tried and is known to be practicable.

1. A temperature stage.

The response of protoplasmic movement to variations of temperature, even if not a topic of much importance in itself, is worth studying as a fine example of quantitative response to external influences, and especially as an introduction to the exact statistical method of studying physiological phenomena. It is not, of course, for beginners, but for those of middling grades. For this work a temperature stage is necessary, preferably one for each student; but those on the market cost from $7 upwards. An efficient stage that can be made by any plumber at small cost is shown in *fig. 1*. It is of sheet copper, one-sixteenth of an inch thick, of the breadth of a microscope stage, rolled over as shown by the figure to make a chamber for a thermometer and another for a three-inch slide, with holes for the light. For-

ward it dips down to enter a shallow (one inch deep) tin box which hangs from it by one cross wire and two stubs, as in the figure. Both stage and box taper forward to one inch and one and one half inches respectively, a feature not necessary though it diminishes leverage when the box is full. A battery clamp, properly filed, holds the apparatus to the stage of the microscope, and a mat of felt between prevents conduction of heat to it. The

FIG. 1.—A temperature stage.

ordinary thermometers necessary for other purposes about a laboratory may be used, or bent ones, more easy to read, may be obtained at little advance over the straight kind. To raise the temperature, the box is filled with water and heated by a spirit lamp; to lower it, the box is filled with ice and salt. Every degree of temperature may thus be obtained, from below zero to boiling. If the student, observing stamen-hairs of Tradescantia or Nitella, uses an eyepiece micrometer and a metronome ticking seconds, the rate of movement under each degree of temperature may be obtained with the greatest nicety. The

minimum, optimum, and maximum may be determined precisely, and all results tabulated and plotted in curves, an exercise of great pedagogic value to those beginning exact work in physiology.

It may be thought that the thermometer, being further from the source of heat than the slide, may register a lower temperature. This, however, is not appreciably so, as shown by one stage I had made with thermometer chambers both proximal

FIG. 2.—A clinostat.

and distal of the slide chamber. In this both thermometers registered practically alike unless the temperature was being raised with great rapidity, which is in any case not permissible because of its abnormal effects upon the protoplasm.

2. A clinostat.

It is most astonishing that so vastly important and illuminating a subject as irritability should receive so little attention as it does in our elementary courses. It is the clearness and

ease with which this and some other fundamental biological phenomena may be illustrated in plants that makes botany, properly used, an indispensable factor for training in biology. Very much can be done in its illustration with no appliances at all, though for the satisfactory demonstration of some of its most important phases, a clinostat is necessary. The cheapest clinostat on the market is Wortmann's, costing $50, a very efficient instrument. Where, however, as in elementary work, it is the *principle* of geotropism or heliotropism that is to be illustrated, and not their manifestations in some particular plants or their parts, the arrangement shown in *fig. 2* is ample. A Seth Thomas eight-day clock is altered by a clockmaker so that its minute hand revolves once in fifteen minutes (to keep within ordinary reaction time).[1] The hands and surplus wheels are removed, and over the spindle thus left a brass sleeve is fitted, bearing at its outer end a thin brass disk, two inches in diameter, with a few holes in its edge, revolving in a plane parallel to the clock face. When the clock is horizontal this disk will carry a small flowerpot and when vertical it will carry also a considerable weight though hardly a pot. For illustrating geotropism, one takes two corks about five inches in diameter and an inch thick and pins to each of them soaked beans in the five different extreme possible positions; each is then covered with damp chopped sphagnum moss which fills a thin crystallizing dish of a size to cling to the beveled edge of the cork over which it is firmly pressed. The seeds should be brought out to the heads of the pins nearly an inch from the cork. One of the corks is now fastened to the brass disk by tacks put through the holes in the edge of the latter and is kept revolving in a vertical plane on the clinostat. The other near by, under the same external conditions, is kept fixed in one position. In three days the results are most instructive, and, indeed, this experiment leaves nothing to be desired in the beauty of its illustration of this particular subject.

[1] I believe that in my instrument this was accomplished partly by shortening the hair spring, and partly by removing each alternate tooth from the escapement wheel.

The best beans I have found for the purpose are horse beans. which are little liable to mold, while chopped sphagnum moss is the best medium I have found for growing seeds in almost any physiological experiments. The entire apparatus costs less than ten dollars.

3. A self-recording auxanometer.

The study of growth in the higher plants, and of how it is influenced by external conditions of light, temperature, moisture, etc., is always an important topic in an elementary course, and for it a self-recording auxanometer is needed. Many forms have been devised, but none has come into general use, except the well-known Albrecht form, which costs over $100. I have made a fair instrument, shown in *fig. 3*, constructed as follows: Take a dollar clock and remove hands, face and all surplus wheels, which will leave a round steel spindle three-fourths of an inch long projecting above the works. Have turned on a lathe a hardwood cylinder, twelve inches long and an inch in diameter, with a hole turned in one end truly in the center, a little smaller than the steel spindle of the clock. The cylinder is then forced down on the spindle and stands vertically and firmly, revolving once an hour. Have turned also on a lathe a double wheel as shown in the figure, the larger as thin as possible, six inches in diameter, grooved on the edge, and the smaller an inch in diameter, the whole carefully and lightly varnished with shellac to prevent warping. Through the axis of this double wheel a small smooth hole is turned on the lathe, and by this hole the wheel turns on a clean new fine needle soldered horizontally to a firm support. The wheel will revolve on the needle with very slight friction. A fine silk thread carefully and finely waxed (to prevent hygroscopic absorption of water) is attached in the usual way to the tip of a vigorously growing part (such as a flower stalk of hyacinth), run several times around the small wheel, and fastened by a tiny drop of glue. A similar thread is run in reverse direction around the large wheel twice and fastened. The other end carries the pen against

the cylinder. The pen is made from a piece of small glass tubing sharply bent so that both ends press against the cylinder, one end being open and smoothed and the other drawn out to a capillary point bent to press at right angles against the cylinder.[2] It is then partly filled with chronograph ink. The cylinder is covered with thin smooth paper put on moist with one edge gummed down so that when dry it is without wrinkles. Enough weight is added to the pen to make the wheel turn as the plant grows, and as growth occurs the pen descends, tracing on the paper a spiral line. If now a vertical line be ruled on the cylinder, the length of the parts intersected by the spiral line will give the exact growth per hour, of course magnified. If half-hour intervals are needed, another line is ruled 180° from the first, and the paper between the two removed on one side, when the edges may be brought together, giving half-hour intervals. Of course these records may be removed from the cylinder for preservation. There may not be room for pot and clock under the wheel and either they must be put upon different levels, or else the thread from the plant must be run through a fine screw eye or other smooth arrangement as shown in the figure. This instrument is liable to the same errors as

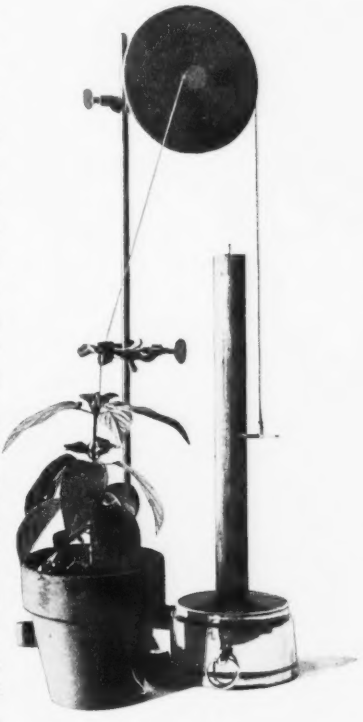


FIG. 3.—A recording auxanometer.

[2] The figure shows an earlier and less efficient pen.

the Albrecht, but with large vigorous plants it gives results which, if not exact, are sufficiently so to be very instructive to beginners. It need not cost much over $2.

4. An osmometer.

The absorption of water by roots cannot be omitted from an elementary course, and osmosis must be demonstrated, necessitating some form of osmometer. A most efficient one is the following: Cut off an ordinary burette about 2^{cm} below the beginning of the graduation and smooth the end in the flame. Over it push for a centimeter or more a soaked Schleicher and Schüll diffusion shell of 16^{mm} diameter,[2] which will fit the burette exactly, and tie it very tightly with several turns of waxed thread. Fill shell and burette up to the zero mark with molasses, and immerse the shell in pure water. The rise of the liquid will be very pronounced and rapid, and may be measured on the graduated tube.

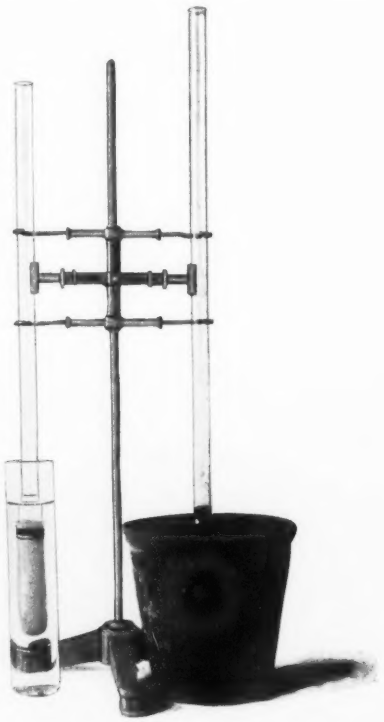


FIG. 4.—An osmometer.

This experiment is most instructive when performed along side of another in which a similar burette is attached by rubber tubing to the cut stump of a vigorous plant with a stem about the

[3] These may be obtained at a low cost from Eimer and Amend, New York.

diameter of the burette. The water will rise vigorously. We then have side by side two similar burettes, to one of which innumerable tiny absorbing hairs are attached, and to the other a single huge one. It is true there is the difference between them that the root hairs have a semi-permeable lining of protoplasm absent from the shell, and that they do not open directly into tubes as the shell does, but these differences are of minor account in comparison with the fact that it is fundamentally the same physical force that produces the absorption in the two cases.

5. A respiration apparatus.

Of prime importance in plant physiology is the exchange of gases in the processes of respiration and photosynthesis. It is

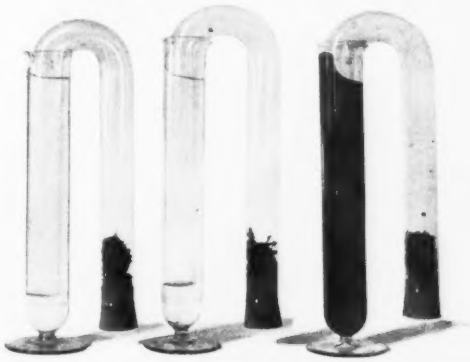


FIG. 5.—Respiration apparatus.

the more important in elementary courses, since nearly everybody, with the reciprocal exchange between animals and plants in mind, fails even to recognize that respiration exists in plants. It helps greatly to clear a student's mind on this subject if the nature and importance of respiration are made plain to him before he has had a chance to confound its processes with those of photosynthesis. The germination of seeds offers a good chance to demonstrate the gas exchange in respiration uninflu-

enced by that in photosynthesis, and it may logically be demonstrated as follows:

Take three test tubes on feet (*fig. 5*) or their equivalent, and fill each half full of, respectively, (1) pure water, (2) strong caustic potash, (3) mixture of concentrated caustic potash and pyrogallic acid. Take three U-tubes of somewhat smaller diameter than the test tubes, and in one end of each place about twenty soaked fresh radish seeds, or else a few soaked oats, placing under each lot a wad of moist sphagnum, and shut them in by a tight rubber cork. The other ends of these tubes are to be placed in the three test tubes. It will be found after a few hours that the pyrogallic mixture had risen in the U-tube about one fifth of its length. This is because it has absorbed the oxygen, and it is the most convenient way to get rid of oxygen from a small space. These seeds do not germinate, or only very slightly (probably from intramolecular respiration, though possibly because not all of the oxygen has been removed). In the tube with the potash, in a day or two, the liquid has risen to about one fifth of the length of the U-tube, and the seeds have germinated. The rise is of course due to the absorption by the potash of the carbon dioxide given off by the germinating seeds. In the tube with the water the liquid rises but little though the seeds germinate freely. This part of the experiment is necessary in order to prove that it is not simply the absorption of the oxygen that allows the liquid to rise in no. 2, but that an equivalent volume of another gas is given off.

This experiment logically proves, (1) that oxygen is necessary to growth; (2) that oxygen is absorbed in growth; (3) that carbon dioxide is given off in growth; (4) that oxygen absorbed and carbon dioxide given off in growth are equal in volume. Thus is respiration demonstrated.

In setting up the pyrogallic tube it is practically best to place the pyrogallic acid in the end of the U-tube and the concentrated caustic potash in the test tube. U-tubes, instead of straight tubes with the seeds at the upper end, are best, because in the latter case moisture runs down from the wet seeds and potash diffuses up the streams and kills the seeds.

6. A germination box.

A student's introduction to botany is best made through the study of living plants that are doing something characteristic. Practically it is difficult, and in city schools generally impossible, to make such studies out of doors, and the best substitute I know of is to provide each student at the start with seeds whose germination and growth he can watch. Of course these can be grown in pots or boxes, in sawdust, cotton wool, etc., but after much trial I have found a germination box like *fig. 6*,

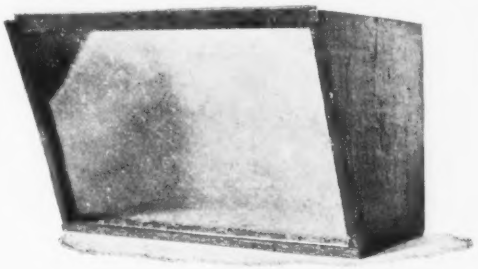


FIG. 6.—Germination box.

filled with chopped sphagnum moss, the best apparatus. It is eight inches in length by six in extreme breadth and five in depth, with a sloping glass side slipping into a groove. The rough edge of the glass is protected by a strip of wood, as shown in the figure. These boxes are made in quantity at box factories for eight cents each without glass, and cost not over twelve cents each complete. When well painted they may be used many years in succession. The great advantage of the sloping glass side is that it allows the roots to be studied, not only the tip, hairs, and branching, but also their geotropic positions. The latter are particularly instructive when the glass is tipped in the same plane through 45°. In fact, the box is practically that used to such profit by Sachs. The sphagnum not only permits the seeds to grow well, in this being the best medium I know, but it allows them to be removed without injury to the roots, and it is very clean to work with. The student may keep

the same box and follow development of the same seedlings for several weeks.

7. A transpiration device.

In preparing plants for transpiration weighings it is usual to wrap the pot in rubber cloth. This prevents the condition of the pot with respect to water being seen, and limits the supply of oxygen to the roots. If, instead, the pot be placed in a thin glass dish slightly larger in diameter than the pot, and one to two inches higher, it will be necessary only to roof it over with rubber, which is much easier than wrapping the whole plant; the condition of the soil may be seen and more or less water given as seems needed; and the oxygen supply for the roots is more nearly normal. Of course plant and glass are weighed together.

8. The graduation of roots, tubes, etc.

In experiments on growth and geotropism, one often needs to graduate roots, which is done with insoluble India ink. But when the ink is applied with a pen or brush, it generally runs and is very uneven in breadth of the lines. If a fine thread, kept stretched by the spring of a piece of wire, be used, and the ink placed on and allowed to soak into it, marks of perfect evenness and any desired breadth may be made by the thread. It is of course equally good for glass tubes. The thread and spring may be mounted conveniently in a needle-holder. A small frame could be made with threads 1^{mm} apart and parallel, with which a root could be graduated perfectly in one operation.

9. A root-pressure gage.

Root pressure is so important a subject that an efficient gage for its measurement is much needed. None, however, is available; the apparently simple S-shaped tube containing mercury, figured in most books, cannot be made to work without great difficulty. *Figure 7* shows a form which, while liable to some errors, yields, nevertheless, approximately correct results. A tube six inches or less long, with a good glass stop-cock at the top, is graduated, as just described, into convenient small divisions, and is then attached to a stump of a vigorous plant

whose stem is about the diameter of the inside of the tube into which it slips a little. The attachment may be made by putting on the stump close to the glass a short piece of rubber tubing about as thick as the glass of the tube; a joint of larger rubber tubing is slipped over the glass and the smaller piece, and is then wound tightly with tire tape which will not yield to pressure from within. Such a joint will be pressure tight. A little water is poured into the tube with a pipette and brought to some zero mark. The stop-cock is then closed. As the water rises in the tube it will compress the air column, and the approximate amount of pressure exerted may be measured by Mariotte's law, *i. e.*, under constant conditions the pressure is inversely proportional to the volume of the air. Of course the successive readings should be taken as nearly as possible at the same temperature. The water vapor in the tube is a source of error, but not an appreciable one if the readings are taken at constant temperatures.

FIG. 7.—Root pressure gage.

All manometer gages used for such purposes as this are liable to an error not always recognized, in that they assume the *quantity* of water available for exerting pressure to be unlimited, whereas in fact it is always limited. If the plant be small and the gage be large, the plant may not give off quantity enough to push the registering fluid up to the point which it should reach in order to register the true pressure under which the water actually is given off. Hence these gages are likely to register pressure more accurately the smaller they are.

SMITH COLLEGE, NORTHAMPTON, MASS.

OOGENESIS IN PINUS LARICIO.

WITH REMARKS ON FERTILIZATION AND EMBRYOLOGY.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XIV.

CHARLES J. CHAMBERLAIN.

(WITH PLATES IV–VI)

IN the autumn of 1896, while conducting laboratory work in the special morphology of the gymnosperms, I noticed puzzling peculiarities in the development of the nucleus of the oosphere, but the material lacked important stages and had not been properly fixed for cytological study. The next spring, however, at intervals of three or four days, ovules of *Pinus Laricio* Poir were collected which gave a fairly complete series from the separation of the neck cell from the central cell of the archegonium up to stages in which the embryos had been thrust through the base of the oospore by the elongating suspensors.

For the earlier stages up to the cutting off of the ventral canal cell, the pair of ovules was merely cut off from the scale and dropped into the killing fluid; for stages from this point to the fusion of the pronuclei, the female gametophyte (prothallium) was usually removed from the ovule to insure rapid killing and fixing. In a part of the material, however, the nucellus was retained to show the course of the pollen tube to the oosphere. In all the later stages the gametophyte was removed from the ovule. All material was fixed on the spot, nothing being taken from cones which had been removed from the tree for more than fifteen minutes. In some cases as many as twenty ovules were taken from a single cone and kept in a separate bottle. These showed almost an identical stage of development. This uniformity occurs also in the sporangia of staminate cones in which the pollen mother cells undergo division at nearly the same time, the sporangia at the base being only slightly more

advanced than those at the tip. In the ovulate cone, at the time of the division of the mother cell into potential megaspores, the sporangia at the base are slightly more advanced, but they do not develop much further. For stages figured in this paper, the best material is found in the middle three fifths of the cone.

In my material, all of which was collected in the vicinity of Chicago, the ventral canal cell, in the season of 1897, was cut off about June 21, and fusion of the pronuclei occurred about a week later. In the season of 1896, all stages appeared more than two weeks earlier.

Various fluids were used for killing and fixing. For mitotic phenomena the most satisfactory results were secured by allowing Flemming's weaker solution to act for about two hours and then replacing it by a chrom-acetic solution (0.75^{gm} chromic acid and 0.25^{cc} to 100^{cc} water) in which the material remained for one or two days. In this way the advantages of the Flemming's solution seem to be secured without the objectionable blackening. The chrom-acetic acid used alone gave excellent results. Carnoy's fluid (absolute alcohol 6 parts, chloroform 3 parts, acetic acid 1 part), followed by cyanin and erythrosin, is good for tracing nuclei in the pollen tube and for differentiating the granules and network within the nucleus. Corrosive sublimate-acetic acid could hardly be recommended for achromatic structures in Pinus. Hermann's fluid and Merkel's fluid failed to give as good results as the much less expensive chrom-acetic acid. The popular safranin gentian-violet orange combination gave the most definite stain for achromatic structures-but Haidenhain's iron-alum-haematoxylin used alone, or followed by acid fuchsin, was better for most stages in the development of the oosphere nucleus.

THE VENTRAL CANAL CELL.

No attempt was made to secure a complete series of early stages leading up to the condition represented in *fig. 1*, which shows the nucleus of the central cell just before the division separating the ventral canal cell from the oosphere. At this stage there is often only a single nucleolus, and very seldom

more than two or three. This is worth noting, for the oosphere nucleus, soon after the cutting off of the ventral canal cell, contains a very large number of nucleoli. The chromatin is extremely scanty, unless, perhaps, it is in a diffuse state or forms a part of the nucleoli.

The mitotic figure concerned in the cutting off of the ventral canal cell presents a very characteristic appearance. The spindle is strongly developed and the part lying in the oosphere is sometimes quite convex, while the part within the ventral canal cell is concave (*fig. 2.*) The ventral canal cell usually begins to show signs of disorganization almost as soon as it is cut off. In this figure the nucleus had evidently reached the spirem stage before it began to disorganize. A similar difference between the nucleus of the ventral canal cell and that of the oosphere at this stage was noticed in several cases. In *fig. 3* the nucleus had developed further before disorganization set in, for a fully formed nuclear membrane is present and the chromatin is in the form of nucleoli or irregular masses. It is not unusual for the ventral canal cell to become separated from the egg as shown in this figure. In such cases the separation is due to the splitting of the wall between the two cells, and in some cases, even when no separation has taken place, as in *figs. 6* and *7*, the wall can be seen to be double. A later stage is shown in *fig. 5*, in which the ventral canal cell is reduced to a deeply staining mass, probably of mucus-like consistency, in which no structure is discernible. *Fig. 4* represents a ventral canal cell of about the same age as the preceding, but the chromatin is not so abundant and the other cell contents are scanty. It does not seem probable that such a cell, in its later stages, would present the appearance shown in *fig.* 5 or exert such an influence upon the course of the pollen tube as might be expected in the latter case. In both *fig. 5* and *fig. 6*, the nuclear membrane has entirely disappeared, and no structure can be made out except that the mass is more or less homogeneous and contains a few nucleoli. That the nucleoli here represent the chromatin is proved by a very complete series, of which only a few stages (*figs. 2, 3* and *5*) are figured.

In later stages it may be difficult to identify the ventral canal cell as a whole, but vestiges of it in one form or another can usually be found up to the time when the pollen tube enters the neck of the archegonium, and occasionally traces may be seen even after the sporophyte is considerably advanced (*fig. 19 a. v.*).

While the above account gives the usual history of the ventral canal cell, there are other rather exceptional cases which belong to an opposite course of development and are interesting on account of their bearing upon the homology of the ventral canal cell. *Fig. 7*, which is drawn to the same scale as *fig. 2*, shows an enormous spindle, somewhat loosely attached to the daughter nuclei. This ventral canal cell is eight or ten times as large as the typical one shown in *fig. 2*. It contains several proteid vacuoles like those of the oosphere, and its nucleus is undergoing the usual developmental changes which will be described for the nucleus of the oosphere. In this particular case, the nuclei of the oosphere and ventral canal cell are of nearly the same size and are in the same stage of development. If a pollen tube should enter, it seems reasonable to suppose that fertilization of the ventral canal cell might result. A later stage in such a course of development is represented in *fig. 10*, in which the nucleus has almost reached the condition presented by an oosphere nucleus just before conjugation. In *fig. 8* the nuclei are in about the same stage as in *fig. 7*, but the wall between the ventral canal cell and the oosphere has broken down, leaving both nuclei free in the oosphere. Fragments of the immense spindle are scattered throughout the oosphere. In some of these a strong line represents a part of the cell plate; in others the fibers are drawn into wisps resembling tips of bipolar spindles. A similar case is shown in *fig. 9*, but here the nuclei have nearly reached the size and stage of development shown in *fig. 17*. Still another example is shown in outline in *fig. 19a, v.* In *figs. 7–10*, the nucleus of the ventral canal cell, on account of its more favorable position, would be more likely to secure fertilization than the more remote nucleus of the oosphere. One might

suggest that a stage like *fig. 9* represents the two pronuclei within the egg, or that fertilization has already taken place and the two nuclei are the first two nuclei of the sporophyte. While the series shown in *figs. 7, 8*, and *9* affords an answer to such suggestions, it may be added that vestiges of the pollen tube can almost always be detected above the neck of the archegonium until the oospore nucleus has divided two or three times. No evidences of fertilization were visible in these cases, and, besides, the upper nucleus is far too large for a male pronucleus just escaped from a pollen tube. If fertilization has not taken place, the second supposition is already excluded; but it may be added that the nuclei are too large for the first nuclei of the sporophyte, they lack the very characteristic appearance of the latter, and, further, their position is against any such interpretation.

The origin of the ventral cell has led several writers to regard it as the homologue of the egg. That this homology is correct, the series just described furnishes practically complete proof as far as origin and function can furnish it, the only thing lacking being an actual case of fertilization.

THE DEVELOPMENT OF THE OOSPHERE NUCLEUS.

The development of the nucleus of the oosphere differs decidedly from the usual course of development ascribed to the nucleus of the angiosperm oosphere. After the cutting off of the ventral canal cell, the nucleus of the oosphere increases enormously in size, as will be readily observed by comparing *figs. 2* and *17*.[1] During this increase in size, there takes place in the nucleus a series of changes which for some time it was difficult to interpret. In *fig. 2* the nucleus of the oosphere does not differ much in size or in any other perceptible respect from the nuclei in the sheath about the oosphere. In this figure the nucleus is in a typical spirem stage. The numerous and often coarse radiations about the nucleus were not observed in similar

[1] All the figures are drawn to the same scale except 14 and 15, and the outline sketches, 9, 19*a*, 24*a*, 25*a*, 26*a*, and 27*a*.

stages of prothallial cells. From this point the development is so extremely rapid that, in over three hundred preparations, less than a dozen nuclei showed stages intermediate between *figs. 2* and *11*. One of these is shown in *fig. 6*, *n. o.* (The proteid vacuoles, *p*, bear a striking superficial resemblance to nuclei.) In this nucleus nearly all the chromatin is in the form of nucleoli. A few linin threads are present, and associated with them is a very small quantity of chromatin. In other nuclei of about the same age, *figs. 7*, *8*, no linin is visible, and all the chromatin is in the form of nucleoli. The greater number of these nucleoli stain blue with cyanin and erythrosin, but some stain red. The mere size of the nucleoli has no influence upon these reactions. I have not felt it safe to rely upon staining reactions for identifying chromatin, but have depended upon a close morphological series leading up to undoubted chromosomes. After all trace of the original linin network has disappeared and all the chromatin is in the form of nucleoli, another rather peculiar linin network appears. This and all the nucleoli stain intensely with iron-alum-haematoxylin. At first sight it would seem that we are dealing with a chromatin network, but if the second application of iron-alum be sufficiently prolonged, only a few of the nucleoli remain black, the stain being completely extracted from the network and from the rest of the nucleoli (*fig. 11*). If acid fuchsin be added to such a preparation, the network and the decolorized nucleoli stain red. A later stage, in which the decolorizing has not been carried so far, is shown in *fig. 12*. Details from nuclei in slightly later stages than *fig. 12* are shown in *figs. 14* and *15*, in which nearly all of the nucleoli are arranged upon the linin threads. Soon after this stage, the network begins to resolve itself into a granular substance, thus leaving the nucleoli scattered irregularly throughout the nucleus. Some of the nucleoli contribute to the granular substance, while others migrate from all directions toward a certain point, usually at the center, or a little above the center, of the nucleus. In *fig. 16* the network, while still distinguishable, has begun to break up, and nearly all of those nucleoli which

stain black with iron-alum-haematoxylin have taken a characteristic position. Some, however, which do not retain the stain, are scattered through the nucleus. *Fig. 17* shows a somewhat later stage. Only traces of the network are now visible; the granular condition is becoming quite pronounced and the nucleoli are arranging themselves in the form of a ring. The structure within this ring I was not able to make out definitely, but in most cases it seemed to be finely granular, with traces of threads more or less defined.

In *fig. 18* every vestige of the network has disappeared, and the nucleus is filled with an evenly granular substance. Nearly all the nucleoli have collected at the center. In *fig. 19* the groundwork of the nucleus shows a beautiful reticular structure, exactly like that of the cytoplasm outside the nucleus. The nucleoli are taking the form of elongated masses which represent definitely the chromatin of the nucleus. The threads seen in the central area are a part of the general reticulum.

The development of the male pronucleus was not studied in detail, but several stages, one of which is shown in *fig. 13*, indicate that the sequence is similar to that just described for the nucleus of the oosphere.

It seems probable that various bodies have been described under the term nucleolus. That some of these nucleoli represent chromatin has been proved both in animals and in plants. In animals the sequence described by Carnoy and Lebrun[2] for batrachians agrees more nearly with the conditions in Pinus. That the chromatin in the resting nucleus of Spirogyra is in the form of a nucleolus has been shown by several investigators, notably by Mitzkewitsch[3]. A chromatin nucleolus is also described by Davis[4] for Corallina, one of the red algæ. A relation between chromatin and nucleoli has been noted in the

[2] La vésicle germinative et les globules polaires chez les batrachiens. La Cellule **14**: 113–200. 1898.

[3] Ueber die Kerntheilung bei Spirogyra. Flora **85**: 81–124. 1898.

[4] Kerntheilung in der Tetrasporenmutterzelle bei *Corallina officinalis* L. var. *mediterranea*. Ber. d. deutsch. bot. Gesell **16**: 266–272. 1898.

higher plants, especially by Cavara[5] and very recently by Duggar[6].

Ikeno's[7] figures and description of *Cycas revoluta*, while not dealing with details in the development of the nucleus of the oosphere, nevertheless indicate that the sequence is about as I have described it for Pinus. Blackman's recent work on *Pinus sylvestris* will be considered later. The staining reactions do not seem to furnish a reliable method of distinguishing chromatin nucleoli from other spherical bodies. In thin sections some nucleoli show a sharp differentiation into an outer deeply staining portion and an inner part which stains lightly (*fig. 29*). *Fig. 28* shows a peculiar case. There seemed to be a crack in the nucleolus, and upon applying a gentle pressure the central portion came out from the shell. It might be suggested that the presence or absence of this outer portion, or, when present, its relative thickness, may account in some measure for the reaction to stains. That the staining does not identify chromatin nucleoli is shown by the fact that many of the "nucleoli" in the proteid vacuoles stain intensely black with iron-alum-hæmatoxylin, blue with cyanin, or red with safranin.

FERTILIZATION.

Strasburger's[8] figure of Picea shows conjugating nuclei of equal size. According to Coulter[9], one of the male nuclei in *Pinus Laricio*, after its entrance into the oosphere, increases in size until, at the moment of fusion, it is as large as the female pronucleus. In Ikeno's figures of Cycas, and Blackman's [10] of *Pinus*

[5] Intorno ad alcune strutture nucleari. Atti del R. Istituto Botanico dell'Università di Pavia **5**: 1–49. 1897.

[6] On the development of the pollen grain and embryo sac in *Bignonia venusta*. Bull. Torr. Bot. Club **26**: 89–105. 1899.

[7] Untersuchungen über der Geschlechtsorgane und den Vorgang der Befruchtung bei *Cycas revoluta*. Jahrb. f. wiss. Bot. **32**: 557–602. 1898.

[8] Befruchtung u. Zelltheilung. Leipzig. 1878.

[9] Notes on the fertilization and embryogeny of conifers. Bot. Gaz. **23**: 40–43. 1897.

[10] On the cytological features of fertilization and related phenomena in *Pinus sylvestris*. Phil Trans. Roy. Soc. of London. B. **190**: 395–426. 1898.

sylvestris, the male pronucleus is many times smaller than the female. In the present work, although the male pronucleus was often observed within the oosphere, no case was found in which the pronuclei were just coming into contact.

One fine preparation was obtained which shows the chromatin of the two pronuclei within the original limits of the female pronucleus (*fig. 20*). Both pronuclei are in the spirem stage, and show the chromatin granules evenly distributed upon a delicate linin thread. The kinoplasmic threads seem to be developing almost exclusively in the region of the male pronucleus, but it is hardly safe to draw any conclusions. A later stage, which I am not ready to interpret, is shown in *fig. 21*. The spirem thread has become perfectly smooth and has the same diameter as a chromosome in the anaphase of the first division of the fusion nucleus, but the segmentation into chromosomes is not yet complete. It seems possible that the upper group represents the male pronucleus, and the lower the female.

The first division after fertilization (*fig. 22*) shows a beautiful figure with a very strongly developed spindle, some of its kinoplasmic threads reaching from pole to pole while others merge insensibly into the surrounding groundwork of the nucleus. The chromosomes are very definitely U-shaped. After the second division has taken place and the four free nuclei have begun to move toward the base of the oospore, they show a characteristic tangential striation (*fig. 23*) which seems to be caused by a rotation of the nuclei as they descend. In the first division of these four nuclei, after they have reached the base of the oospore (*figs. 24, 24a*), the spindle is extremely broad and multipolar, but in later divisions (*figs. 26, 26a*) the spindle is of the usual bipolar type. This figure gives a typical view of the U-shaped chromosomes as they appear in these divisions, just before becoming separated from each other. Although several early phases in mitosis were found in the nuclei of the partially segmented portion of the oospore (*figs. 25, 25a*), no later stages were obtained. A fairly complete series was obtained showing mitosis in sporo-

phytes older than that represented in *fig. 26*. These show that the chromosomes do not resolve themselves into nucleoli, but pass into an ordinary reticulum.

A peculiar monstrosity was noted in one preparation (*figs. 27, 27a*). Instead of the usual free cell formation, each division of the nucleus has been followed by the formation of a wall, so that a somewhat spherical embryo has been formed near the center of the oosphere, about which no trace of a pollen tube could be found.

ARCHOPLASM AND CENTROSOMES.

After the large spindle concerned in the separation of the ventral canal cell from the oosphere has broken up, portions of it become scattered throughout the oosphere (*figs. 8, 19a*). One of these fragments (*19a, s.*) is shown in detail in *fig. 32*. Some of these fragments (*fig. 31, s*) in their later stages show a perfect transition from kinoplasmic fibers to the ordinary reticular structure of the oosphere. Such cases, together with those like *fig. 22*, make it probable that the kinoplasmic fibers do not arise from any specific kinoplasmic or archoplasmic substance but rather from a rearrangement of general reticulum, whether it be outside the nucleus or inside. Such a view, while not popular with botanists, has able supporters among zoölogists.

I was not able positively to identify centrosomes at any time during this work, but in several preparations clearly defined areas resembling the archoplasmic regions in Ascaris were observed near the male nuclei in the pollen tube (*fig. 13*.) The failure to find centrosomes has not convinced me that they are absent from the male nuclei.

The archoplasmic areas shown in *fig. 12* were observed in only one case, although nearly a hundred nuclei in approximately the same stage were examined. These areas, one inside the nucleus and the other outside, are sharply differentiated and are giving rise to rather coarse threads. This is not the usual method of spindle formation for this nucleus and may have nothing at all to do with the spindle.

BLACKMAN'S WORK.

After this paper had been practically completed, there appeared a very important work on *Pinus sylvestris* by Mr. Blackman (*l. c.*) Since this work has already been reviewed in the March number of this journal, only a brief comparison will be made here. I can confirm his statements that the pollen tube does not enter the oosphere; that the pronuclei at the time of fusion are not in the resting condition; that the history of the spindle fibers indicates that they result from a rearrangement of the ordinary cytoplasmic reticulum; and that the number of chromosomes is twelve in the pollen mother cell, in the nuclei of the sheath of the oosphere (*fig. 30*), and in other parts of the prothallium.

My second series (*figs. 7–10*), on the development of the ventral canal cell, was not observed by Blackman. His term maturation is not used, because it already has a definite and very different application. The term metaplasm is not used in the present paper because the network is regarded merely as a somewhat peculiar *linin* network. In the development of the nucleus of the oosphere, he neither figures nor describes the chromatin history in detail, but the points mentioned do not indicate the sequence decribed in this paper. He finds the chromosomes of the first segmentation nucleus V-shaped; *fig. 22* of this paper shows them U-shaped. He figures parallel threads around the four segmentation nuclei; although this appearance was occasionally noted in my preparations, the fibers usually had the arrangement shown in *fig. 23*. On the whole, it must be said that, while the two papers cover approximately the same ground, the more detailed work of each, having been done in different parts of the subject, is complementary. The general results, however, are to a great extent mutually confirmatory.

SUMMARY.

1. While the ventral canal cell usually disappears soon after it is formed, in some cases it persists and its nucleus becomes as large as that of the oosphere, passing through a similar develop-

mental history. New support is thus given to the theory that the ventral canal cell is the homologue of the egg.

2. In the development of the oosphere nucleus the chromatin takes the form of nucleoli which finally collect from all parts of the nucleus to a definite area near the center and there develop into a typical spirem. The linin often stains like chromatin.

3. After the male pronucleus is within the oosphere nucleus, the chromatin of the two pronuclei appears as two distinct masses in the spirem stage. Perhaps segmentation of the two spirems occurs while they are still separate.

4. Although centrosomes were not positively identified in any part of the work, appearances favor the supposition that they may accompany the male nuclei.

5. The fate of the spindle indicates that the kinoplasmic fibers arise through a transformation of the cytoplasmic reticulum.

THE UNIVERSITY OF CHICAGO.

EXPLANATION OF PLATES IV–VI.

A Zeiss 2^{mm} apochromatic homogeneous immersion objective and compensating ocular no. 4, with camera lucida, were used for all drawings except *figs. 14* and *15* (comp. oc. no. 18) and the outline sketches *9*, *19a*, *24a*, *25a*, *26a*, and *27a*, which were made with low power dry lenses. All drawings are reduced one half in photo-engraving.

Abbreviations: n. o., nucleus of oosphere; *n. v.*, nucleus of ventral canal cell; *p.*, proteid vacuole; *s.*, portion of spindle; *v.*, remains of ventral canal cell.

FIG. 1. Nucleus of central cell before cutting off the ventral canal cell.

FIG. 2. Cutting off of the ventral canal cell.

FIGS. 3, 4, 5. Three views of the ventral canal cell.

FIG. 6. Apex of the oosphere, showing nucleus of oosphere, proteid vacuoles and the ventral canal cell.

FIG. 7. Extremely large ventral canal cell and spindle connecting it with the nucleus of the oosphere.

FIG. 8. The wall between ventral canal cell and oosphere has broken down, leaving the nucleus of the ventral cell free in the oosphere. Fragments of the spindle scattered through the oosphere.

FIG. 9. Similar to the preceding, but more advanced.

FIG. 10. Ventral canal cell with nucleus developed nearly to the fertilization stage.

FIGS. 11, 12, 16–19. Stages in development of nucleus of the oosphere.

FIG. 13. Two male nuclei in end of pollen tube just as it enters the neck of the archegonium.

FIGS. 14, 15. Nucleoli arranged on linin network; details from nuclei slightly older than *fig. 12*.

FIG. 19*a*. Sketch in which *n. o.* shows position of *fig. 19* and *s* the position of *fig. 32*.

FIG. 20. Fertilization.

FIG. 21. Later stage in fertilization.

FIG. 22. First division of the nucleus of the oospore.

FIG. 23. One and part of another of the four segmentation nuclei showing felt-like covering, with tangential threads predominating.

FIGS. 24, 24*a*. First division of one of the four free nuclei after passing to the base of the oospore.

FIGS. 25, 25*a*. Spirem in nucleus in the partially segmented portion of the oospore.

FIGS. 26, 26*a*. Nuclear figure showing shape of the chromosomes.

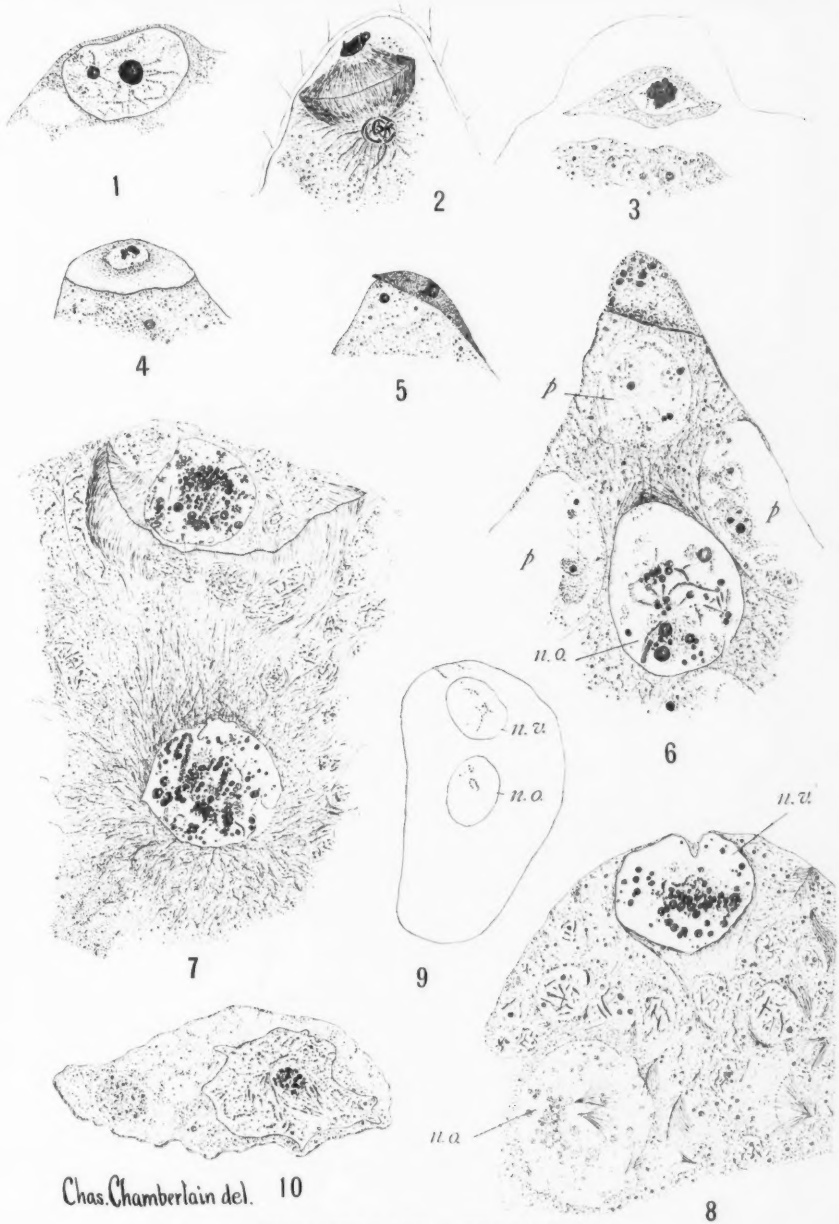
FIG. 28. Nucleolus showing deeply staining outer and lightly staining inner portions.

FIG. 29. Inner portion of nucleolus pressed out from the outer "shell."

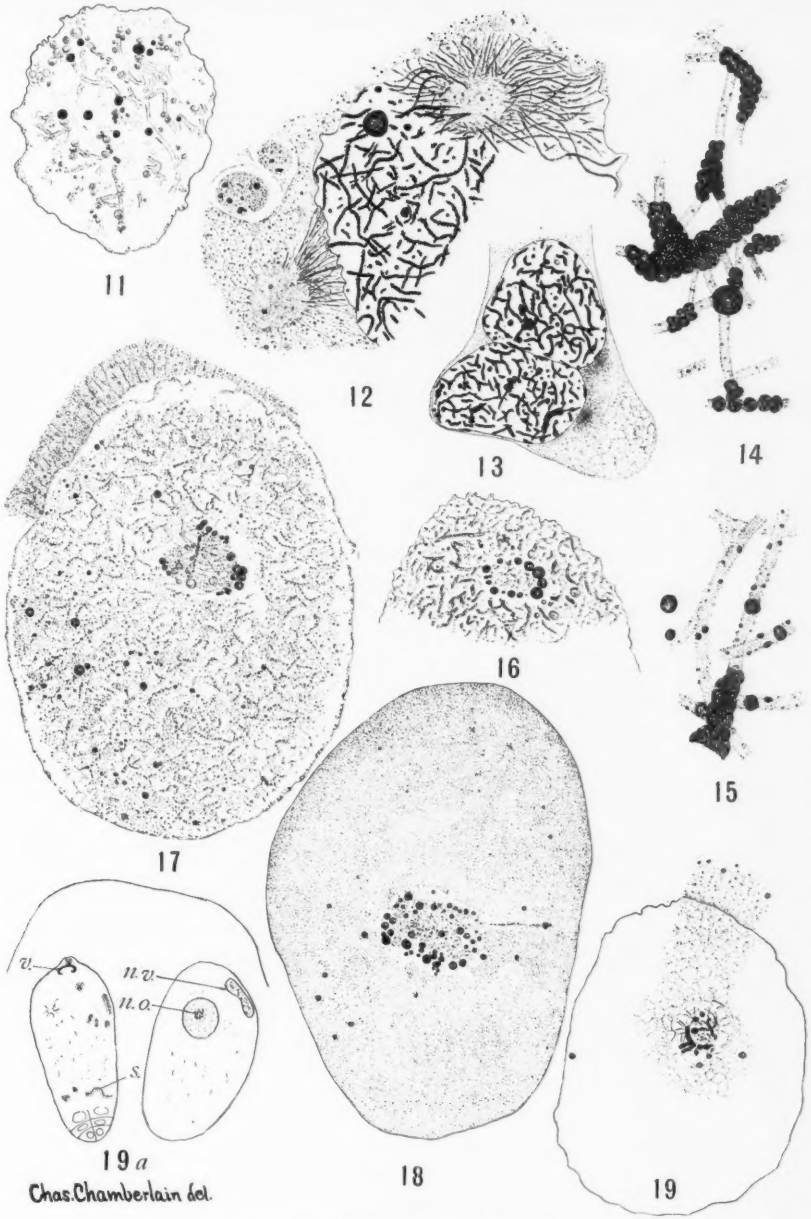
FIG. 30. Nucleus of one of the cells sheathing the oosphere, showing the twelve chromosomes.

FIG. 31. Fragments of the ventral canal cell spindle showing transition between spindle fibers and cytoplasmic reticulum.

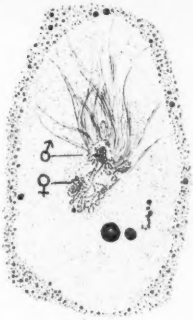
FIG. 32. Fragment of spindle. See *fig. 19a, s*.



CHAMBERLAIN on OOGENESIS



CHAMBERLAIN on OOGENESIS.



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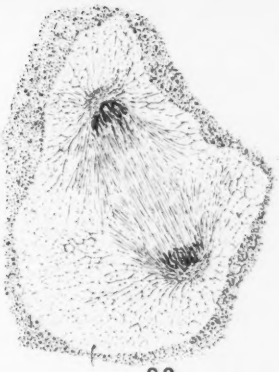

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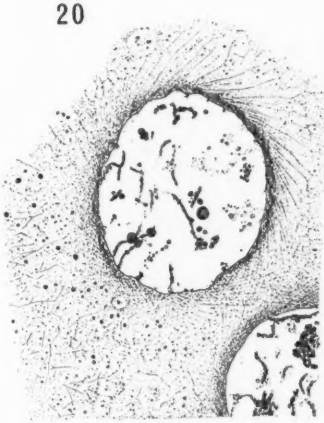

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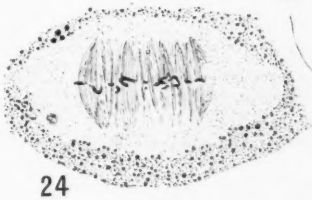

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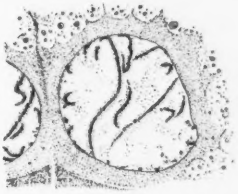

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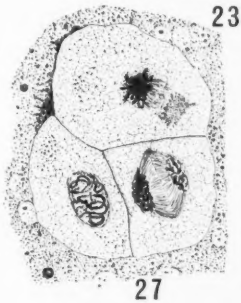

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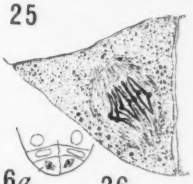

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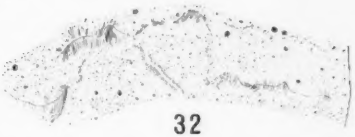

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Chas. Chamberlain del.

CHAMBERLAIN on OOGENESIS.

THE ECOLOGICAL RELATIONS OF THE VEGETATION ON THE SAND DUNES OF LAKE MICHIGAN.

HENRY CHANDLER COWLES.

[*Continued from p. 202.*]

3. *Encroachment on preexisting plant societies.*

THOSE who are at all familiar with wandering dunes are acquainted with their power to destroy vegetation in the path of their advance. This, indeed, is to many people the most conspicuous feature of a sand dune area, because it often becomes a feature of the greatest economic importance. The effect of an advancing dune upon the preexisting vegetation varies greatly as conditions vary. The most important factors are the rate of advance, the height of the advancing dune above the territory in its path, and the character of the vegetation that is encroached upon.

The rate of advance is, of course, a decidedly variable factor, since all rates, from nothing up to the maximum rate, may be found along nearly all advancing lee slopes. At a given point the rate varies greatly during different seasons. An advancing portion may become checked and a checked portion may advance again, as wind-sweeps are clogged up or opened once more. The multiform changes on the complex, each and all, affect the rate of advance to a remarkable degree. Attempts have been made to measure the maxima of advance at Dune Park, but a sufficient time has not elapsed as yet to allow of any satisfactory conclusions. In November 1897 a stake was driven at the basal edge of a rapidly advancing lee slope. The height of this stake above the ground was a little more than a meter. In May 1898 the stake was nearly covered, and it could not be found at all in July. At this point, therefore, the vertical component of advance amounted to a meter in six months; the horizontal component, of course, was greater still,

FIG. 9.—General view at Dune Park, showing the encroachment of a dune on pools, swamps, and forests. Dune crest in the left background, oak dunes at the right. Wind ripples in the foreground. View taken in winter.

FIG. 10.—A doomed forest of basswoods, etc., at Dune Park. Dunes encroaching from all sides, but somewhat slowly; dune at right advancing in the direction of the prevailing wind. Thicket of basswood, dogwood, etc., at the left background. Subsequent vegetation in the foreground (grape at right, chokecherry at left).

since the angle of slope was about 30°. The general statement may be made for the Dune Park complex that the maxima of advance are to be measured in decimeters or meters per annum, rather than in centimeters or decameters. No estimates can be given for other localities. In all probability the Glen Haven dunes move more slowly, since the slopes have a much richer vegetation.

The height of an advancing dune above the territory in front of it is a very important factor, inasmuch as it often determines the life or death of a flora. At Glen Haven, where the advancing dunes are from thirty to sixty meters high, no preexisting vegetation can survive the burial which awaits it. At Dune Park, where the crest is never as much as thirty meters high, vegetation sometimes survives. This survival is determined chiefly by the nature of the vegetation, and the succeeding paragraphs will have to do with the struggle between dunes and floras at Dune Park.

The advancing dunes at Dune Park encroach now upon a swamp, now upon a forest. *Fig. 9* shows how these forest and swamp conditions alternate. In the right foreground is a pool, surrounded by bulrushes. Toward the center of the photograph there is a ridge tenanted by pines and oaks, then another swamp and another ridge. *Fig. 10* shows a very interesting phenomenon. At the center is a deep trough, surrounded on all sides by advancing dunes. This trough has never been a wind-sweep, but was made by the piling of the sand all about it. The flora in this depression is not a typical sand-dune flora, although surrounded by such on all sides. It is a mesophytic island in a xerophytic sea. The dominant trees in this little group are the basswood, *Tilia Americana*, and the ash, *Fraxinus Americana*. Although the basswood is common on the arrested dunes, this plant society is quite evidently a relict of a larger area developed under more genial conditions. The lake is toward the right, and the dune on that side is advancing with some degree of rapidity. The dune to the left is pushed forward in the main by the action of southerly winds, and moves quite

slowly. This dune, however, is at the upper end of the curved wind-sweep previously mentioned, so that northwest winds contribute to its advance. Thus it becomes possible for the same wind to cause the advance of two dunes toward each other and hasten the burial of a flora. The advance of all dunes at this point is relatively slow, as is shown by the comparatively abundant vegetation on the advancing slopes. This vegetation is not a relict of the past. The advancing dunes completely destroy all of the preexisting vegetation at this point. In a few more years, unless conditions change, there will be nothing left at the surface by which one may interpret the history of this dying plant society.

The encroachment of a dune upon a forest is shown in *figs. 11* and *12*. The forests in this vicinity consist principally of the scrub pine, *Pinus Banksiana*, and the black oak, *Quercus coccinea tinctoria*. Neither of these trees can survive any such degree of burial, as can the cottonwood. The oak, especially, succumbs long before the entire tree is buried; the dead trees along the dune margin in both pictures are oaks. *Fig. 12* shows a pine that is half buried, but apparently as vigorous as ever. The dead trees in *figs. 15* and *16* are mostly scrub pines, and they seem to show no greater adaptation to their new surroundings than do the oaks. There appears to be a wide range of individual adaptation in pine trees, some dying almost as soon as the dune reaches them at all, while others are nearly as resistant as the cottonwood. In both pines and oaks the first obvious sign that the tree is waging a losing struggle is etiolation. The living trees along the margin (as in *figs. 11* and *12*) rarely have a dark green foliage. In most cases the leaves are yellowish green, and in some cases almost white. Nor are the leaves as numerous or large as on healthy trees.

Such tree groups, as are shown in *figs. 9*, *10*, *13*, and *14*, are doomed to an inevitable death. The length of life allotted to them in the future depends almost entirely upon the rate of the dune's advance. There are some evidences in favor of the view that an individual pine tree can endure a deeper covering before

FIG. 11.—Encroachment of a dune on an old and long-established oak dune at Dune Park. Dead oak trees at the margin.

FIG. 12.—Encroachment of a dune upon an oak forest at Dune Park. Bugseed in the left foreground. Half buried but vigorous pine at the center. Dead oak trees at the margin.

death ensues, if the rate of advance is slow. *Fig. 12*, which represents a half buried pine that is still vigorous, was taken at a point where the advance is relatively slow. *Figs. 15* and *16*, on the other hand, where the pines were soon killed, represents one of the most rapidly advancing dunes at Dune Park. Thus the individual adaptation referred to in the preceding paragraph may be in part delusive. Perhaps the trees are able to adapt themselves more fully, and hence undergo a greater degree of covering before they die, where the advance of a dune is comparatively slow. Sometimes (as in *fig. 11*) the territory toward which the dune advances is higher than the dune itself. In such a case the advancing dune is checked. If the entire area in front is higher than the dune, the sand gradually accumulates until the altitude is great enough to permit another advance. When, however, a ridge meets the advancing dune at right angles (as in *fig. 9*), the dune's course is deflected to either side. If the ridge is high enough, some of the trees may be able to escape the fate of their associates. The pines in the background of *fig. 17* probably represent a portion of the flora at the top of one of these ridges.

At Glen Haven, as has been stated, the forest vegetation readily succumbs, because of the great height of the advancing dune. The forests are mainly of two types, the maple or the arbor vitae. The maple forests have a dominance of *Acer saccharinum*, and represent the most common type of mesophytic forest in that part of Michigan. The arbor vitae forests are in reality swamp forests, and the most typical trees present there are *Thuya occidentalis*, *Betula papyrifera*, and *Fraxinus Americana*. The line of dead trees along the margin of the advancing dune (as shown to a slight extent in *figs. 11* and *12*) is particularly striking where there is an encroachment upon a maple forest. Sometimes the hemlock, *Tsuga Canadensis*, grows with the maple and shares its fate. At one point the dune encroaches upon a forest of *Pinus Banksiana*, and the results are precisely as at Dune Park.

Dunes that are encroaching upon forests may be found along

the entire coast, though their best development is in association with an extensive dune-complex, as at Dune Park or Glen Haven. The burial of forests was observed at Frankfort, Muskegon, and elsewhere, and is a relatively common phenomenon. In closing up the treatment of the forests, the general statement may be made that an advancing dune destroys the entire forest vegetation. Where this rule meets with any exception, it is an exception that in no real sense invalidates the main proposition.

The encroachment of a dune upon a swamp is of less common occurrence than encroachment upon forests, because forests are so much more common than swamps along the lake shore. The best examples of dunes advancing on swamps were seen at Dune Park, where there are a number of swamps that run more or less parallel with the lake shore. *Fig. 9* gives a good impression of the general appearance of things in the vicinity of Dune Park. In the foreground is a pool and bulrush swamp upon which the dune is encroaching. Beyond the wooded ridge at the center is another swamp of the same type, which is suffering the same fate. In the distance there can be seen the crest of a dune, which is advancing upon a chain of forest-clad hills.

The dune which is shown in the foreground of *fig. 9* encroaches upon a pool in which there is an abundance of aquatic plants, such as *Nymphaea odorata*, *Nuphar advena*, and *Pontederia cordata*. These plants are soon destroyed, of course, but it is surprising how long it is before they die. Leaves of Nymphaea and Nuphar have often been seen raised above the sand, a meter back of the present margin of the pond. These plants must have been partially buried for some weeks, and yet the leaves were scarcely blanched at all. Indeed, an oak tree buried to an equal relative depth would have succumbed entirely. Around the margin of the pool is a luxuriant growth of the bulrush, *Scirpus lacustris*. This plant soon gives up the struggle, etiolation being present when only the basal portion of a stem is buried. The appearance of the bulrush is often striking by reason of the fact that there are etiolated rings alternating with green rings of stem tissue.

FIG. 13.—Steep lee slope of a rapidly advancing dune at Dune Park. Encroachment on a sedge swamp and pine bottom. Complete destruction of preexisting vegetation. Beachlike fringe of moist sand at the base of the dune.

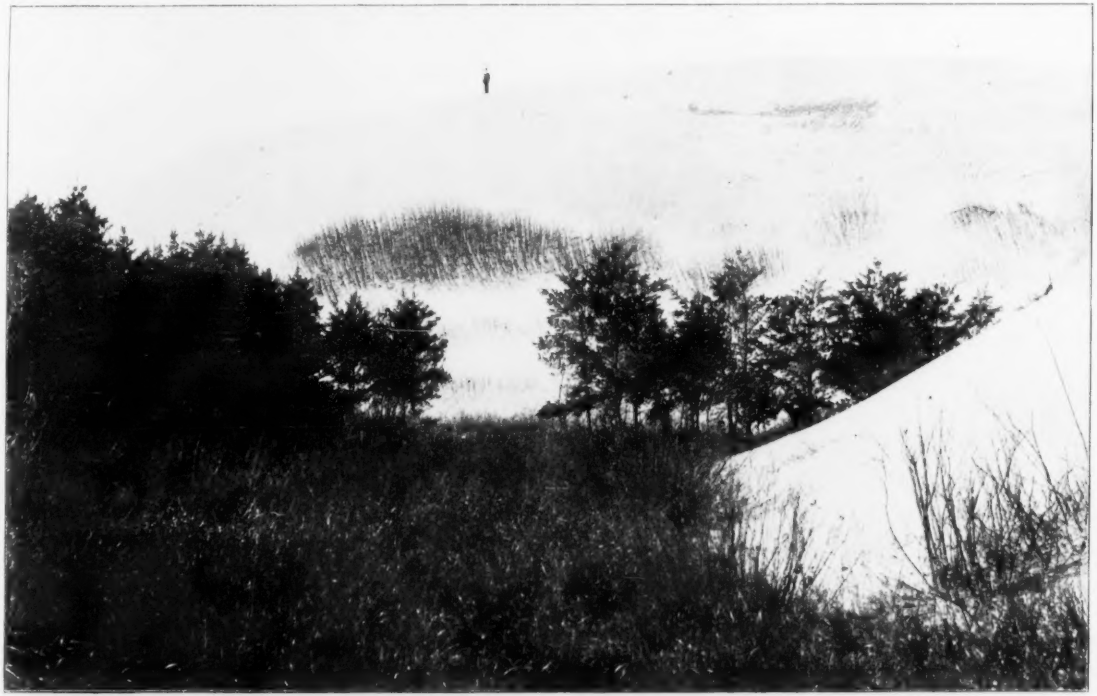

FIG. 14.—Steep lee slope of a rapidly advancing dune at Dune Park. Encroachment on a swamp and pine bottom. Pocket in the dune with pines. Dogwoods on the slopes. View taken in winter.

Fig. 13 shows the encroachment of a low dune upon a sedge swamp. The beachlike fringe of sand at the base of the dune is peculiar to dunes that encroach on swamps. Considerable sand rolls or is blown beyond the base of the steep slope. Under ordinary conditions this sand is blown away, but as soon as it reaches the wet, swampy ground, it becomes moist, and hence remains for a time as a fringe to the dune. The plants of a sedge swamp are unable to adapt themselves to a dune environment, and quickly succumb. *Fig. 14* shows a dune advancing on a more mesophytic flora and on a group of pines. The effect here is also destructive, in the main. An interesting pocket in the dune, in which there is a group of pine trees, appears in this figure.

One of the most remarkable phenomena seen in the dune region is shown in *fig. 15*. A dune about twenty five meters in height is advancing with considerable rapidity upon a bulrush swamp. This swamp is more or less continuously surrounded by a marginal fringe of willows and dogwoods. The bulrushes are quickly destroyed, but the dogwoods and willows have thus far been able to remain not only alive but luxuriant. In order to keep above the sand, these plants are obliged to lengthen their stems far more than is ever the case under normal conditions. Already some of these plants have twice and three times their normal stem height. The buried portions of the stems, particularly of the willows, send out roots almost as soon as they are buried. These plants, therefore, become more and more independent of the deeper soil in which they first grew, thus escaping one of the greatest dangers that was mentioned in connection with many tenants of the embryonic dunes.

Three species have been found that are able to adapt themselves almost immediately to a dune environment, *Salix glaucophylla*, *S. adenophylla*, and *Cornus stolonifera*.[3] The taller shrubs

[3] Some of the *Cornus stolonifera* may prove to be *C. Baileyi*. These two species certainly intergrade in the dune region. The pubescence character is largely a question of habitat. The best determinative character is the stone, and, judged by this, nearly all specimens examined, whether from the swamps or from the dunes, were *C. stolonifera*. See BOT. GAZ. **15**: 38, 86–88. 1890.

in *fig. 15*, as at the left of the center, are *Salix adenophylla*. The lower shrubs are dogwoods or glaucous willows. *Fig. 16* shows a group of the latter two species growing together. How long these plants will be able to endure is a question that cannot now be answered. The conditions become severer each year, because of the necessity for increased stem elongation, and also because the plants are constantly rising above the protected position in the lee of the dune. At no place is the destructive action of the wind greater than at the summit of an advancing lee slope.

The encroachment of a dune upon an open swamp or a body of water is seen occasionally along the Michigan shore, as at Grand Haven. In no case, however, were any facts obtained that added anything essential to those given above. In concluding the section on dune encroachment, it may be said that the only conspicuous case of the survival of members of a preexisting flora is furnished by the swamps. It may at first seem a surprising fact that the plants which are able to adapt themselves to the intensely severe conditions of an advancing dune are hydrophytic willows and dogwoods, rather than mesophytic oaks, basswoods, and maples, or xerophytic pines. Such a view as this comes from a misconception of the change that is needed in the life-habits of the plant. The relation to the soil water is not conspicuously altered, or at least not rapidly altered. It is true that the elongating stem makes it more and more difficult for the plant to draw water from the original root system; but in the case of the willow, at any rate, this is counterbalanced by the development of new roots along the buried stem, which allow the plant to utilize the moisture in the sand. The trees mentioned above are unable to send out such roots, and here, at least, is one possible source of their failure.

There is another line along which the solution of this problem of adaptation may be sought. A number of ecologists in later years have commented on the xerophytic structures of many swamp plants. These structures are not to be found in all swamp plants, but are particularly well-marked in plants of

FIG. 15.—Steep lee slope of a rapidly advancing dune at Dune Park. Encroachment on a bulrush swamp, which has a marginal row of willows and dogwoods. Death of the herbs and pines, but survival of the shrubs through vertical elongation, enabling them to rise above the sand.

FIG. 16.—Section of the lee slope shown in *fig. 15*. Dogwood and glaucous willows at the center (antecedent). Scattered dead pines. Subsequent vegetation consisting of trailing and climbing grapevines, cedar, and bugseed.

undrained swamps, *e. g.*, peat bogs. Schimper even goes so far as to regard peat bog plants as xerophytes, because the humus acids in the soil make it difficult for plants to obtain the requisite amount of water. Consequently peat bog plants have worked out xerophytic structures to reduce the transpiration. All of the swamps at Dune Park are undrained swamps, and may be called potential peat bogs. The chemical nature of the soil is such that the plants have doubtless adapted themselves to all of the essential conditions of a xerophytic life. The partial burial of these plants by a dune results, as has been seen, in no rapid change of relations with the water in the soil. The aerial organs, however, are exposed to a greater degree of light and heat by reason of their proximity to the sand. Thus the tendency to transpiration is increased, but the plants may be able to keep it within bounds through the xerophytic structures that have already been worked out in a swamp environment. It is likely, too, that these structures become more and more xerophytic as a result of life on and in the dune.

The theories that have been exploited in the preceding paragraph find, at least, a partial confirmation. The leaves of the three successful species have more or less pronounced xerophytic structure. The leaves of the dogwood are quite strongly pubescent. The willows, however, are more decidedly xerophytic. The leaves of *Salix adenophylla* are very hairy, and the cuticle is thick. *Salix glaucophylla* has leaves with a very thick cuticle, and coated on the under surface with a dense layer of bloom. In the dune form of this latter species the leaves are notably thicker and the bloom more dense. It is the author's intention to make a careful comparative study of the anatomical characters of these plants, and make report in the second part of this paper. All three of the species named above have a remarkably wide range of habitat, occurring on embryonic dunes, arrested dunes and heaths, as well as in swamps and on lee slopes. These shrubs may grow at almost any altitude and show a surprising independence of the water level in the soil. There seems to be scarcely any doubt, therefore, but

that these species are naturally adapted to a xerophytic life, and that, when the occasion arises, still further xerophytic conditions can be met successfully.

The success of the willows and dogwoods on the dunes may be due, in part, to yet another characteristic. It is well known that swamp plants are provided with extensive adaptations to promote aeration. This need is especially apparent in undrained swamps, where the gases necessary for the underground tissues and organs have to be almost entirely supplied from above the surface of the soil. It is in these undrained swamps, too, that the accumulation of peat is so rapid. It seems rational, then, to suppose that tenants of undrained swamps, by adapting themselves to prevent suffocation, have also adapted themselves to withstand burial by sand without injury. Just what is the cause of death, when plants are partially buried by the soil, is, so far as the author knows, an unanswered question. A wide field for anatomical study and physiological experiment lies open along this line. In the meantime the notion that plants of undrained swamps are better fitted to suffer partial burial than are other plants may remain as a tentative theory.

In considering the formation of secondary embryonic dunes, mention was made of *Potentilla Anserina*, *Cephalanthus occidentalis*, and *Polygonum Hartwrightii* as dune-formers under certain conditions. Potentilla and Polygonum are extensively creeping herbs, while Cephalanthus is an erect shrub. All three are swamp plants naturally, and yet able, as has been said, to build low dunes of a slow growth. In like manner they sometimes remain living for a time when a wandering dune encroaches upon them. They are especially plastic where the advance of a dune is relatively slow. Among these plants Potentilla seems to be the most adaptable to dune conditions. Another swamp plant that shows a surprising degree of plasticity is *Hypericum Kalmianum*. This shrub is very common in the undrained swamps of the dune region, and very often finds itself in the path of an advancing dune. Hypericum, like Salix, often forms a marginal fringe about a swamp, and miniature lines of this shrub are

frequently to be seen toward the base of an encroaching dune, resembling the line of willows and dogwoods shown in *fig. 15*. Of course, Hypericum has nothing like the plasticity and endurance of Salix; nevertheless it may live for many years if the dune advances slowly. Its capacity for vertical elongation is much less than that of Salix or Cornus, so that a rapid advance would soon cover the plants and cause their death. Near the South Chicago beach is a pool with a dense vegetation of *Scirpus pungens* about its margin. This plant has served to collect a small amount of sand, and is forming a low secondary dune. Although a large portion of each shoot is covered by the sand, there is as yet no sign of etiolation on the aerial parts of the plant.

Since the highest portion of a wandering dune is close to its advancing front, it is evident that a buried forest will gradually become uncovered, as the dune passes on beyond. No scene in all the dune area is more desolate than such a place. It is a veritable graveyard, where the corpses once buried are exposed again. *Fig. 17* shows a pine graveyard which has had a history like this. In the background are several living pines, presumably members of the same forest with the others. Their position at the summit of a hill permitted them to survive, while those at lower levels were buried by the sand. The uncovered pine trunks are directly in the path of the main wind currents, and hence are subjected to the severest action of the sand-blast. The trunks are carved and battered away until the last remnant of the old vegetation passes away forever.

Graveyards similar to those at Dune Park occur on the extensive dune-complex at Glen Haven. The commonest dead tree there appears to be the arbor vitae, though there are occasional dead trees of birch and ash. In addition to the trunks of trees, there is an abundance of resurrected soil lines at all altitudes on the complex. These black streaks in the sand vary greatly in depth and persistence. Doubtless the organic matter thus exposed is sometimes utilized by the scanty vegetation on the complex, but more commonly it is rapidly scattered by the winds.

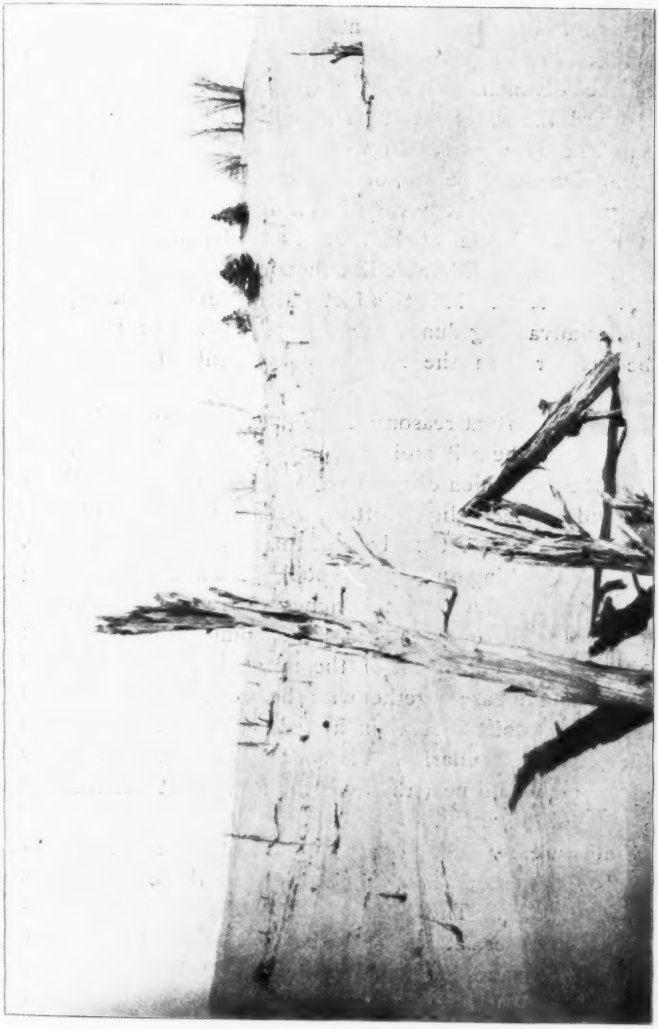

FIG. 17.—Pine graveyard at Dune Park. Forest once buried and destroyed; the dead trees now exposed again. Surviving members of the old pine forest in the background. This area is now a gentle windward slope, and has been converted into a wind-sweep. Carving and battering of the old trunks by sand-blast.

4. *Capture of the dune-complex by vegetation.*

The capture of a dune by plants may begin within the dune-complex itself or along its margin. In either case the first appearance of the advancing vegetation is commonly in the lower places toward the water level. The reasons for this fact are obvious. These low places are well protected from the wind; there is no danger, therefore, of any sand-blast action on the plant organs nor any removal of soil from around the roots. When the growth begins at the foot of an advancing lee slope, there is, however, considerable likelihood that the plants will be covered by the sand. It is this fact which prevents the capture of a rapidly advancing dune; the vertical growth of the plant must be greater than the vertical component of the dune's advance.

The most important reason for the first appearance of plants at lower levels is the soil moisture. It is the moisture at the surface of the soil which causes to a large degree the lodgment of seeds, and especially light cottony seeds like those of the cottonwood and willow. At the base of the dune shown in *fig. 9*, where it is encroaching on a swamp pool, there is a line of young cottonwoods and willows several inches above the level of the pool. The seeds were blown across the complex by the wind; when they reached the crest of the advancing lee slope, they rolled down to the base together with the sand. The base of the dune is always moist several inches above the surface of the water because of capillarity. As soon as the sand and seeds reached the moist soil near the base, the movement was checked and both found lodgment.

The moisture necessary for the germination of the cottonwood and willow seeds is also furnished at these low places near the water level. The danger of being covered by the drifting sand is much less at this place because moist sand is more compact than dry sand, and because moist sand does not collect about the growing plants. The dune shown in the foreground of *fig. 9*, however, is advancing very rapidly, and it is not likely that the growth of the young plants will be rapid enough to pre-

vent their being covered. In the moist sand at the base of the dune shown in *fig. 9* patches of algæ have been seen, presumably Chlamydomonas, such as have been described in connection with the lower beach. It is doubtful if these algæ are of any significance in the capture of dunes.

If the vegetation gets a foothold at the base of an advancing slope, it tends to creep up the slope by means of vegetative propagation. At the base of the cottonwood dune shown in *fig. 5*, there may be seen grasses which appear to be creeping up the slope in this manner. It should be borne in mind that such appearances are often deceptive. In this particular instance the appearance would be the same if the dune were advancing and the grasses rising to keep above the sand. In like manner there is doubt with regard to *fig. 16*, as to which vegetation antedates the dune and which is subsequent. As has been already stated, the clump of dogwoods and willows at the center beyond all question antedates the dune; so too, the dead half-buried pines. The annual bugseeds toward the base, of course, are subsequent.

The greatest doubt is as to the frost grape, *Vitis cordifolia*[4]. At the upper right hand there is a luxuriant grapevine climbing over a dead pine. The clumps back of the willows and the trailing vines in front of them are also Vitis. *Fig. 15* shows several large grapevines back of the row of willows. The coarse-leaved vines at the lower right hand of *fig. 10* are also Vitis. It seems incredible that the vines in this last picture should be anything else than subsequent, since the height of the sand above the wooded hollow is more than twenty meters. Then too the Vitis vines are very abundant all along the coast on the naked dunes, but are rarely found elsewhere. On the dune shown in *fig. 15*, for instance, there are two willows, a dogwood, and the grape growing together. The dogwood and one of the willows are very common in the adjoining swamp, while the grape was not found there at all. On the other hand, no grape seedlings have as yet been found in any such location. While much further study is

[4] The identification here may be questioned; fruiting specimens are rather rare, but prove to be this species so far as examined.

needed in this connection, it seems likely that Vitis is subsequent to the dune.

A little above the center to the left in *fig. 16* is a young cedar, *Juniperus Virginiana*. This little plant is several meters up the slope and is unquestionably subsequent. In the left foreground of *fig. 10* is a shrub of the chokecherry, *Prunus Virginiana*, which is certainly subsequent to the dune. In fact this shrub is rather frequent in such locations. The author does not feel clear as to the conditions which permit the germination and development of these plants in such unstable situations, for it must be remembered that the advance is rather rapid in all cases. No seedlings of the cherry, grape, or cedar have been seen in any such location. It may be that the germination and early growth took place when there was a temporary lull in the advance or during extremely moist seasons. The question cannot be fully solved without a careful study of marked plants for several seasons.

So far as the capture of the dune is concerned, it is a matter of no moment whether the vegetation is antecedent or subsequent. All contribute together to the common end. Of the plants mentioned thus far, Corispermum (shown in the left foreground of *fig. 12*) is of no value in dune capture, because of its annual habit. *Prunus Virginiana* and *Populus monilifera* are rarely abundant enough on lee slopes to be of much value, especially because they have little or no vegetative propagation. The only plants which seem to thrive and increase their area of control on rapidly advancing lee slopes are *Salix adenophylla* and *glaucophylla*, *Cornus stolonifera*, and *Vitis cordifolia*. None of these, however, flourish except on the protected slopes. They are unable to grow along the crest, and hence unable to check the constant advance of the sand.

Vegetation seems to be unable, then, to capture a rapidly moving dune. No such dune has been seen where the vegetation has secured a greater foothold than is represented in *figs. 15* and *16*. This dune is in no sense captured; indeed, its progress is scarcely checked. The more vigorous plants may retain an uncertain foothold for a long time, and again they may not.

So long as the crest is unoccupied by plants, the advance will continue almost without hindrance. The life conditions at the crest are so much more severe than on the slope that vegetation is almost certain to be excluded until the advance is checked by physical agencies. For the capture of a rapidly moving dune, a plant species should have the power of rapid germination possessed by the bugseed, the power of vegetative propagation possessed by the willows, the capacity for growth in height possessed by the cottonwood, or even more than that. The growth of the young plant during the first season should be greater than any of the above, so as to more than counterbalance the vertical component of advance during the period of rest. The life cycle should be of very great length. The plant should be able to endure all extremes of heat, cold, and drought, and all degrees of covering by the sand. No plant species in the Lake Michigan region begins to meet all of these requirements, and, as a consequence, the dunes would advance indefinitely so far as vegetation is concerned.

Various physical conditions tend to check the progress of many dunes. As a dune advances farther and farther from the lake, the effective power of the wind which moves it becomes reduced. The energy is largely spent before the crest of the advancing dune is reached, because of inequalities in its path. The wind commonly builds up other dunes between the lake and the main crest; these dunes serve as barriers, and of course check the advance. Occasionally there are hills in front of the advancing dunes; these check the advance temporarily, at least. The primary cause for a permanent decrease or cessation of movement is the decrease or entire loss of available wind energy. Many wandering dunes never advance rapidly at any period of their life-history. This is because their movement is in some other direction than that of the prevailing wind, or because the full force of the prevailing wind is not directed toward their advance, because of physical reasons. Dunes of this slowly moving type are much more common than the other, and may be seen at almost any point along the entire southern and eastern shore.

Whatever the cause, a slowly advancing lee slope is soon captured by vegetation. The process begins just as described above. Vegetation gets a foothold at the base and creeps up the slope. Antecedent plants, like dogwoods and willows, increase their area by vegetative propagation. Annuals, biennials, and even the hardier perennials germinate and successfully develop at all points. There are many plant species whose power of vertical growth is greater than the vertical component of a slow dune's advance. This latter condition is always the chief test which determines the vegetation of a lee slope. As the advance becomes slower, more and more plant species are able to get and retain a foothold on the dune.

The capture of lee slopes by vegetation was well seen in all its stages at Glen Haven and Grand Haven. At first the vegetation may be dominantly antecedent, as in the case at Dune Park. More commonly, however, the vegetation is chiefly subsequent from the start, chiefly because the area that is encroached upon contains no plants that are fitted for a dune life. Where there is no antecedent vegetation, the first plant to get a foothold is commonly *Ammophila arundinacea*. Plants that follow in quick succession are *Asclepias Cornuti*, *Equisetum hyemale*, *Calamagrostis longifolia*. Some dunes are almost completely covered with a dense growth of Ammophila. All of these plants are perennial herbs and all but Calamagrostis have very extensive vegetative propagation, so that the capture of a slowly moving dune is a relatively quick process. With these plants there may grow annuals and biennials, but they are of little or no value in dune capture. The commonest of these is *Corispermum hyssopifolium*.

Before many years have passed shrubs and small trees find an entrance and gradually drive out the herbaceous vegetation described in the preceding paragraph. These herbs are all fitted to grow in the most exposed situations, but are not adapted to shade. The shrub vegetation of arrested lee slopes may be partly antecedent, but not largely so. The most common species of shrubs on recently captured slopes are *Cornus stolonifera* (or *C. Baileyi*), *Salix adenophylla* and *glaucophylla*, *Vitis cordifolia*,

and *Prunus Virginiana*. With these shrubs young trees of *Tilia Americana* are common. A lee slope thicket of Cornus, Tilia, and others of the above plant species is shown at the upper left hand of *fig. 10*.

All of the species named above occur on arrested lee slopes along the entire coast. The species which are peculiarly characteristic of such habitats are Cornus, Prunus, Equisetum, and Asclepias. These four species are found in other associations, but reach a decided climax here. Ammophila, Calamagrostis, Corispermum, Salix (both species), Vitis, and Tilia are almost as common, but have a much wider habitat range. Ammophila, Calamagrostis, and Corispermum are also found in nearly all plant societies thus far discussed, but they disappear entirely as soon as the vegetation becomes dense. The willows are common in many places on the beach and complex, but they too are ruled out as soon as a real forest vegetation gets a start. Vitis grows also on rapidly moving lee slopes, and remains after the forest has begun. Tilia more than all others looks to the future; as will soon be shown, it is the dominant tree of the first forests that grow on the old lee slopes. With the entrance of the basswood, the true dune conditions and the true dune plants are obliged to pass away.

There are other interesting plants that get an occasional foothold on the arrested lee slopes. At several such places at Glen Haven *Betula papyrifera* was seen. Near Chicago this tree does not grow on the dunes at all, although common along the margins of sloughs. It appears to become more xerophytic northward. Exactly the same is true of *Thuya occidentalis*. Possibly the climatic conditions northward are such as to permit plants that grow normally in protected situations to grow where the exposure is much greater. On an arrested dune at Glen Haven where shrubs for some reason are infrequent, *Solidago humilis Gillmani*, *Aster laevis*, and *Achillea Millefolium* grow abundantly with the herbs previously mentioned.

Before tracing the further growth of vegetation on lee slopes, something may be said of the origin and development of vegeta-

tion within the dune-complex. Of course all antecedent vegetation has been long ago destroyed. The capture of the dune must, therefore, be effected entirely by means of plants which germinate and develop on the complex itself. Speaking broadly, the complex is almost entirely composed of windward and leeward slopes. Since the windward slopes are low, it follows that they cover a much larger area than do the other. Perhaps nine tenths of an ordinary dune-complex is directly exposed to the prevailing wind. The capture of any portion of the windward slope is unlikely, because of the combination of exposure and instability of soil. In the summer a somewhat extensive vegetation may develop, made up largely of annuals and biennials. The most abundant of these plants is *Corispermum hyssopifolium*. Other species are *Artemisia Canadensis* (or *A. caudata*), *Cakile Americana*, *Euphorbia polygonifolia*, *Cnicus Pitcheri*. These plants are commonly more abundant in the deeper wind-sweeps than elsewhere, probably because the sand is moister and more stable in the sweeps than at other places. *Fig. 7* shows a very characteristic wind-sweep with its vegetation composed of the bugseed and other short-lived plants.

Although the summer winds are much less severe than those of winter, the effects on the vegetation of the wind-sweeps are often conspicuous. Artemisia and Corispermum plants frequently have the sand blown away from their roots and they are thus obliged to lean over on the sand. The stems become much twisted and the whole plant is shorter and more compact than when developed in more protected habitats. Occasional perennials that may germinate in such places rarely live over the winter. The vegetation develops anew each year and no steps toward capture are taken. The conditions on the lee slopes of the complex are much like those on the main advancing slopes. Of course all of the vegetation is subsequent. The conditions are, perhaps, more severe because more uncertain. Large slopes covered with Ammophila are common on the Glen Haven complex. Permanent capture may sometimes result on such slopes, but it is much rarer than at the slowly advancing edges of the complex.

FIG. 18.—Lee slope on the dune-complex at Dune Park, captured by the long-leaved willow, *Salix longifolia*, and the cottonwood (broad-leaved forms). Dense clumps of the willow due to vegetative propagation.

The most important development of vegetation on the complex is in the "blowouts," or hollows produced by the wind. These depressions sometimes reach down almost to the water level and may be as much as thirty meters below the general level of the complex about them. In these depressions the sand is moist and protected from the severest action of the wind, so that seeds find ready lodgment and a favorable opportunity for germination and growth. The commonest plants observed are the annuals and biennials mentioned just above, and the following perennials: *Populus monilifera*, *Salix longifolia*, *adenophylla*, and *glaucophylla*, *Juncus Balticus littoralis*. Seedlings of the cottonwood and the three willows appear by the thousand, and a large number survive the rigors of the winter. This is the one dune habitat where Juncus and *Salix longifolia* are at all abundant. These two species are marvelously well adapted to inaugurate dune capture. Both of these plants have very extensive powers of vegetative propagation. Rootstocks of this last-named willow often trail along in the sand for ten, twenty, or thirty meters. Thus the plants extend their area up the slopes of the depression on all sides by means of this vegetative increase. *Fig. 18* shows a lee slope on the complex, which has been almost entirely captured in this way. The dense clump of narrow-leaved shrubs at the center is *Salix longifolia*, probably all coming from one or two plants that have spread vegetatively. The broad-leaved shrubs and trees are *Populus monilifera*.

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[*To be concluded.*]

BRIEFER ARTICLES.

ULVELLA AMERICANA.

(WITH PLATE VII)

Ulvella Americana, n. sp.—This form was found with Nitella and Œdogonium near Ann Arbor, Mich., and grew in great abundance on the sides of the glass of a small aquarium in which these algæ were growing.

Though it was found in shallow fresh water at a great distance inland, it undoubtedly belongs to the marine genus Ulvella, the only other known species of which, *Ulvella lens*, was first found by the Crouan brothers in 1859, growing on bits of glass, porcelain, and seaweeds, at a depth of twenty meters in the bay of Brest in France. It has also been found by Hansgirg in several places in the Adriatic sea.

The Messrs. Crouan[1] describe the genus as follows: Thallus green, disk-shaped, 1–2^{mm} in diameter, horizontal, adhering by all its under surface, composed at the center of cells round, ovate or angled, imbedded in a subgelatinous substance, reticulated, and containing in the interior several sporidia. Toward the periphery the cells change to ovoid or rectangular, are much smaller, separated, and arranged in radiating lines either simple or forked at their extremities. A vertical section of the thallus shows the cells to be arranged in almost perpendicular series, and filled with green.

In addition to this description De Toni[2] states that the cells are 12 to 18 μ (rarely 21 μ) in diameter; also that it reproduces by means of zoospores. These are formed in the central cells, 4, 8, or 16 in each, and are liberated by the dissolving of the membrane. According to Wille,[3] however, this is a doubtful genus, as he thinks it might belong to the genus Pringsheimia; but the structure of the chromatophore and the absence of gametes must separate it from this genus, and so the name Ulvella will be retained.

[1] Crouan frères, Ann. d. Sci. Nat. Bot. IV. **12**: 288. 1859.

[2] De Toni, Sylloge Algarum **1**: 148. 1889.

[3] Engler & Prantl, Die nat. Pflanzenfamilien I. **2**: 105. 1890.

Whether this fresh water form is the same species as the marine form is difficult to say, but it would seem that there were differences great enough to make a new species. Certainly in this form there is much less difference in size between the central and peripheral cells than that figured by the Crouan brothers. Also, in quite a number of cases, long gelatinous looking hairs extended from the surface, and a pyrenoid is always present. As these points seem to be characteristic of the fresh water form only it seems best to separate it from *U. lens*, and to make a new species.

In appearance this fresh water species resembles greatly *Coleochæte scutata*, but the absence of all differentiated sexual organs, the presence of many chromatophores instead of one, and the fact that 4, 8, or 16 zoospores may be found in a single cell of the thallus, all indicate that the nature and development are quite different from that genus.

The disk-shaped thallus varies from 1–3^{mm} in diameter, and until it is partly grown it consists of a single layer of cells arranged in radial rows about a center (*fig. 1*). In surface view the cells near the margin are either square, elongated, or wedge-shaped in outline. They vary in length from 10 to 27 μ, and in breadth from 5 to 13 μ. At the center they are nearly circular, and their diameter is 10 to 13 μ. In cross section the appearance is reversed; the cells near the edge being short or flattened (*figs. 2* and *4*), and those at the middle much elongated, their longest diameter being at right angles to the plane of the disk (*figs. 2* and *3*). The whole thallus does not remain in contact with the substratum throughout its life, but while it is still quite small the central cells become loosened from beneath, then increase in size and number so that the whole center arches up above the level of the disc, and often becomes folded in circles between the center and the periphery. Soon division occurs in these cells parallel to the plane of the thallus, so that at the center several layers may be observed (*fig. 5*).

The membrane is gelatinous, though the layer bounding the contents of the cell is more dense than other portions. Neither the gelatinous substance nor the denser membrane shows a blue color either with chloriodide of zinc or with iodine and sulfuric acid. Both become stained with hæmatoxylin, but not with eosin.

So far as was observed, after the first few divisions only periclinal divisions occurred; even new radial rows of cells originated in this way, one or more projections, occurring on the exterior side of the

cell, being then cut off by transverse walls. The long gelatinous hairs observed in the material from the aquarium disappeared in smaller cultures.

The chromatophores, of which there are many in each cell, are small oval bodies closely crowded near the membrane and imbedded in a highly refractive, almost gelatinous looking, liquid. Whether this is simply the protoplasm which surrounds all chromatophores, or whether it is of some special composition was not determined. A single pyrenoid is present near the middle of each cell, and this is surrounded by a starch envelope, somewhat irregular on the surface. The nucleus lies near the pyrenoid, and assumes more or less the shape of the cells in which it exists; that is, in the peripheral cells it is nearly spherical, while in the central cells it is elongated.

Though a disk shape is characteristic of the species when attached to some solid substratum, it is by no means necessary to the plant, and seems to be assumed only when the plant is attached. If it become detached (and it seems to be capable of living indefinitely in this condition), the whole thallus loses all symmetry of structure, and forms simply an irregular mass of cells the same as is noticed when the central portion becomes loosened from the substratum. If a plant be removed from the surface of the glass and put into a hanging drop culture, either in water or in Knop's solution, there occurs an immediate elongation of the cells perpendicular to the plane of the disk, and they stand up, papilla-like, over the whole surface, even at the edge where the cells had been most flattened. In one instance, within four days, division parallel to the plane of the disk had occurred in these cells, and these again divided in all directions, so that the surface of the disk was then covered with little clusters of cells without the least regularity of arrangement, each cluster leading an independent existence (*fig.* 6).

The same holds true if the development be watched from the zoospores. If these become attached on coming to rest the characteristic disk-form is produced (*figs.* 7, 8), but if they rest on the surface of the liquid, or if they rest on a substratum less solid than glass, such as agar, then the development is identical with that when the mature thallus is detached from a solid substratum, except that the cells become somewhat larger, ranging in diameter from 13 to 23 μ (*figs.* 9–12). Division occurs in these cells rather irregularly. A wall may divide a cell into equal or unequal parts, while in other cases one or two

parallel projections are sent out, and these are cut off by transverse walls (*fig. 12*).

Although the plant may be kept under cultivation as a unicellular alga for a period of at least three months, evidently the normal state is a disk form, for, though development in the unicellular condition was very rapid for the first few days, it soon decreased and almost ceased. This slow development is true also of the thalli arising from the zoospores when unattached; they never attain a large size, but this may be due to unfavorable culture methods.

Of different culture media tried, water, various concentrations of Knop's solution, vegetable solution, and agar to which had been added Knop's solution, the last medium proved most favorable, and development, though slow, was evident as long as the cultures were continued.

Reproduction other than by means of zoospores and vegetative division was not observed.

The zoospores (*fig. 13*) are oval or nearly spherical, though sometimes more elongated and slightly broader near their anterior extremity (*fig. 14*). They are 10.5–15.5 μ long and 7.8–13 μ broad. Usually they do not exceed 10.5 μ in breadth. They are noticeable for their very granular appearance, which is due to the presence of globules of oil; these become darkened by osmic acid, and dissolved by chloroform. On account of the great quantities of this oil the structure of the chromatophore could not be determined, neither could vacuoles or a pyrenoid be detected. A large brick-red eye-spot is prominent near the anterior end, and four cilia are present. Either four, eight or sixteen zoospores are formed from the repeated bipartition of the contents of a cell. They are liberated by breaking through the gelatinous membrane while still enclosed in an inner gelatinous envelope; this, however, is quite invisible without use of reagents. They remain in this membrane for a relatively long period, moving almost continually. Some half dozen of these clusters were observed to move for three hours, but the entire period of motion was not determined. During these movements they were observed to change their shapes, becoming more elongated in form, as in *fig. 14*.

On coming to rest they soon become rounded, and begin to divide. Usually they develop directly into a disk or cluster, as the case may be, but on agar with 0.4 per cent. Knop's solution several cases were noticed where two or four zoospores were formed directly from these

cells, before any other division had occurred (*fig. 15*). These zoospores were not seen to be liberated, but they appeared to be perfect, as each showed distinctly an eye-spot.

In the thallus the zoospores are generally formed in the thickened portion near the center and rarely near the edge. Often the whole center of the thallus has produced zoospores, leaving the cells perfectly empty, and many individuals were noticed on the side of the glass that were ring-shaped, as if the center were entirely gone.

Whereas in most other algæ which reproduce by means of zoospores these are usually formed when transferred from nutritive solution to water, or from stronger nutritive solution to weaker, or from agar cultures to liquid, in this species they are formed when the thallus is subjected to any sudden change. As might be expected, they are produced when the disc is transferred from agar to Knop's solution, but they are also produced when transferred from water to Knop's solution, and when transferred from water to agar. They may be formed within twenty-four hours after these changes are made, but often they do not appear until the second day. In some cases nearly the whole thallus was seen to produce zoospores.

After repeated attempts to find the principles governing the production of the zoospores, no results were obtained farther than that, within certain limits, the greater the change of conditions the greater the number of zoospores and the sooner their formation.

Though this alga greatly resembles Coleochæte in appearance, it really is of much lower organization. Its well developed disk form, instead of being inherent in the alga, as in Pediastrum or possibly Coleochæte, apparently is due only to contact, for, whatever the other conditions may be, it cannot be made to assume this form without a solid substratum.

The fact that it so easily reverts to a unicellular state in which there is no differentiation of cells, but each is capable of carrying on all life functions for itself, and the fact that zoospores may arise directly from the germinating zoospores, show a development but little above the strictly unicellular forms. It may possibly be regarded as one of those organisms, as yet so little known, which are transition forms between the lower and the higher algæ, and may assume the nature of the one or the other according to external circumstances.

That it has been found under conditions so very unlike is not easily explained, and the fact that it has been so rarely found, and then in

regions so widely separated, is an interesting problem in distribution.—JULIA W. SNOW, *University of Michigan.*

*** The work upon which the foregoing paper is based was done in the spring of 1898, while the author held a fellowship given to the Botanical Department by Mr. D. M. Ferry, of Detroit.

EXPLANATION OF PLATE VII.

FIG. 1. Portion of a thallus. × 300.

FIG. 2. Thallus in cross section. × 66.

FIG. 3. Section at the center of a young thallus. × 875.

FIG. 4. Section at the margin of a young thallus. × 875.

FIG. 5. Section through the center of an older thallus. × 300.

FIG. 6. Portion of the surface of a disk ten days after removal from glass. × 300.

FIGS. 7, 8. Young thalli developing when attached to glass. × 875.

FIGS. 9–12. Young thalli when not attached to some solid substratum. *Fig. 9*, × 300; *figs. 10–12*, × 875.

FIG. 13. Zoospores. × 875.

FIG. 14. Shape sometimes assumed by zoospores before liberation and occasionally retained after liberation. × 875.

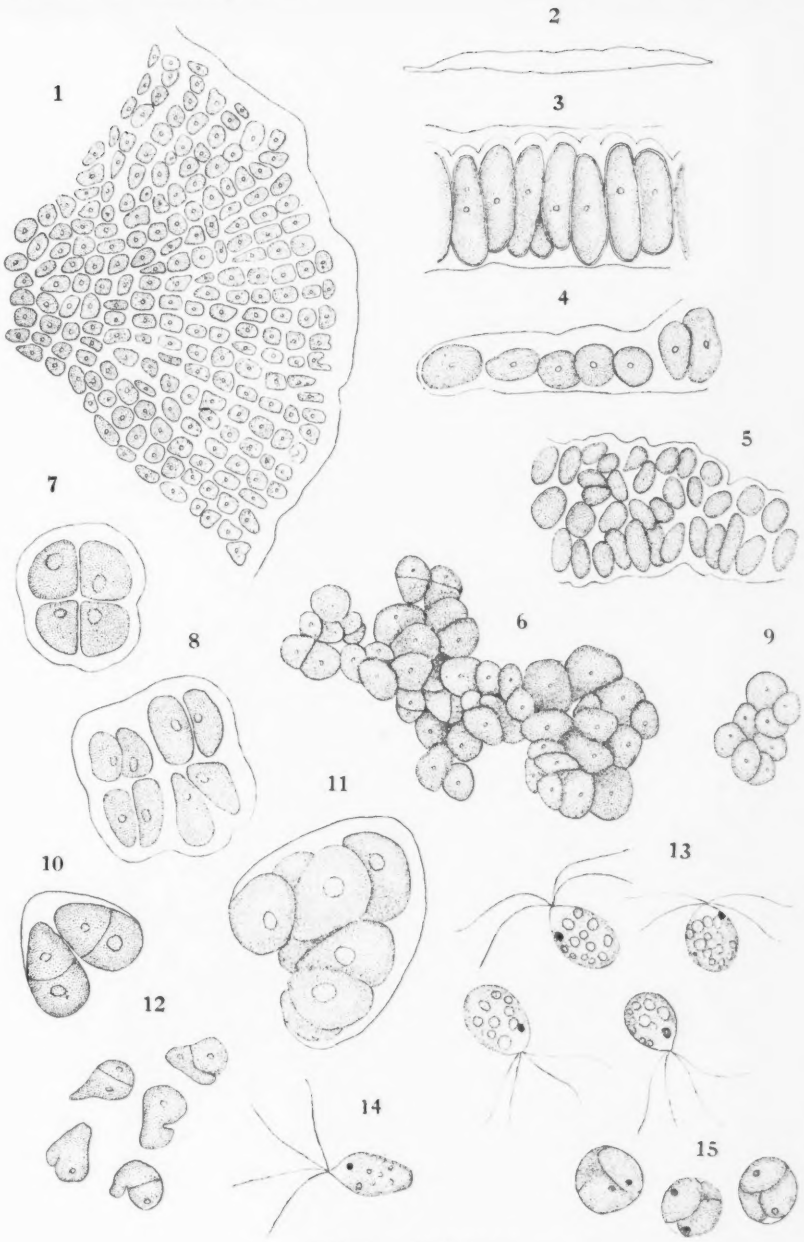
FIG. 15. Zoospores arising directly from germinating zoospores. × 875.

RECENT WORK ON THE LIFE-HISTORY OF THE RHODOPHYCEÆ.

IN Oltmanns' paper upon the life-history of the Rhodophyceæ[1] we have the most recent general expression of opinion on the difficult problems of sexual reproduction and the attendant phenomena of the development of the cystocarp found in this peculiar group of plants. His is the fourth contribution attempting to cover a broad horizon and dealing with the questions in their totality as illustrated throughout the entire class. The three papers that preceded his account were by Bornet and Thuret in 1867, Janczewski in 1876, and Schmitz in 1883.

Of these three papers the first two gave descriptions of the histology and development of the cystocarps of several types, which, for clearness of expression and beauty of illustration, have not been surpassed. One can only express the greatest admiration for the work of Bornet and Thuret, but their investigations, as also those of Janczewski, came before the time of critical cytological study, and consequently

[1] Zur Entwickelungsgeschichte der Florideen. Bot. Zeit. **56**[1]: 99. 1898.



SNOW on ULVELLA.

made no attempt to describe the mechanism and place of the sexual act, that is, the fusion of sexual nuclei. Schmitz, however, formulated explicit theories as the result of his studies, and gave to the world an explanation, or rather, a set of explanations, describing several types of morphological structure and a variety of physiological conditions concerned with the sexual organs. His views have been dominant until very recently.

The most striking features of Oltmanns' contribution is the manner in which he has swung away from the complex and frequently obscure theorizing of Schmitz, and presented an explanation comparatively simple in the demands it makes upon the facts, and perfectly in accord with the stand that biology takes as to the essential conditions and characteristics of the sexual act. To appreciate thoroughly Oltmanns' views it is necessary that one should know the peculiarities of the theories of Schmitz, and wherein they departed so radically from certain general conclusions of biological science.

It is not easy to discuss so complex a subject in a few words. The difficulties lie in the fact that the Rhodophyceæ present a number of different structural characters in the sexual apparatus, making possible a variety of physiological conditions. Thus there is scarcely one genus that is exactly like another as to the detailed morphology of the sexual organs, and, indeed, species of the same genus often differ among themselves.

When one considers how little precise cytological work has been done in the group and how much lies before the investigator, the possible complications that the future may present are not conducive to a feeling of security for any theory applied universally or even generally.

There are two general statements of facts upon which all investigators agree: first, that male cells fuse with a receptive female apparatus, the trichogyne; second, that certain cells, termed auxiliary cells in many types, are stimulated by this phenomenon to produce carpospores. However, the auxiliary cells hold very various relationships to the trichogynes, and these eccentricities have caused the difficulties.

In the simplest cases, as for example Nemalion, the cell that bears the trichogyne itself develops the glomerule of spores, and observations have been reported, according to which it appears that the sperm nucleus passes down the trichogyne and fuses with the female sex-nucleus in the swollen region of the cell below. It seems clear that the physiological conditions during the processes of fertilization in

Nemalion are those of the so-called oosporic type of reproduction, and are not essentially different from the state of affairs described for such a type as Coleochæte. The differences between the two forms are concerned with the morphology of the antherozoid and oogonium (the latter, by custom, termed a carpogonium in Nemalion), and not with the physiology of the sexual act.

But excepting Nemalion and certain related forms that for the most part have not been studied in detail, the other groups of red algæ present various peculiarities. A few examples will be sufficient to illustrate these curious conditions.

In certain species of Callithamnion there are two auxiliary cells, each giving rise to a separate and independent favella of spores. The carpogonium with its trichogyne occupies a position between the two auxiliary cells, but is not connected with either. Indeed, the three structures may be separated from one another by a considerable space. How is the stimulus of a sexual act, taking place in the trichogyne or carpogonium, to be transmitted to the auxiliary cells and excite their development into favellæ of spores? Oltmanns reports some critical observations upon this problem which for a long time has been very perplexing, and they will be referred to in another part of this review.

Dudresnaya furnishes the best known and perhaps most striking peculiarities. Here the auxiliary cells are situated upon widely separated filaments or branches of the frond and often far removed from the carpogonia. The fertilized carpogonium puts forth several filaments that grow among the loosely arranged vegetative filaments and come in contact with the auxiliary cells. At such points the two elements fuse so that the cell-contents mingle, and here are developed the glomerules of spores. Where does the sexual act take place in Dudresnaya, at the points of fusion between the filaments and the auxiliary cells, or previously in the carpogonium? If fertilization is accomplished in the trichogyne or carpogonium, what is the meaning of the second act of fusion at the auxiliary cells?

There are also a number of instances reported, from genera that are not closely related to one another, in such families as the Gigartinaceæ and Rhodomelaceæ. In these there is present one auxiliary cell close by the carpogonium, with which the latter structure fuses directly or by means of a connecting tube. What is the significance of this single auxiliary cell, and what are the cytological phenomena concerned with the act of fusion?

The chief peculiarity of Schmitz's views lay in his theory of a double fertilization, applied to such forms as have auxiliary cells with the phenomenon of secondary fusion, and typified in Dudresnaya. There were two sexual acts. The first occurred when the sperm cell fused with the trichogyne and its male nucleus entered the carpogonium; but a second act of fertilization took place when the fertilized carpogonium, or the filaments derived from this structure, fused with an auxiliary cell. The development of filaments from the carpogonium that were to fuse with auxiliary cells was a device by which the male nuclear substances could be distributed to a number of such elements, thus multiplying greatly the effects of the sexual act.

The extent to which the theories of Schmitz were developed and perhaps extended by his followers, on what seems today a very inadequate basis of fact, need not be considered in detail here. The accounts of various members of the Chylocladiaceæ by Hauptfleisch, and Schmitz's own view of the fusion plate of Corallina are illustrations to the point. The first author stated that in the forms studied by him extensive and indiscriminate phenomena of cytoplasmic and nuclear fusion took place involving not only the sexual elements but various vegetative cells. The present writer believes that he showed the mistake of supposing that in *Champia parvula* this very general cytoplasmic fusion in the vicinity of the carpogonium was a sexual act. The presence of a variable number of auxiliary cells, instead of one, the great extent of the cytoplasmic fusion concerned with these elements, and the fact of the presence in the cells of a great many nuclei that appear to maintain complete independence of one another, all indicate that the unusual phenomenon is not a part of the sexual act but may well be related to nutritive functions. As for Corallina, preparations show that the fusion plate results from the partial absorption of the walls between a layer of cells below the trichogynes. The nuclei apparently remain in their respective positions, and the idea of an extensive multiple fertilization must be abandoned. It appears that Oltmanns himself, although very friendly to much of the work of Schmitz, is not willing to admit the probability of these flights of theory, quite lacking the basis of detailed observations, in a field of cytology offering extreme and peculiar difficulties. The absence of good figures is a serious defect in the papers of Schmitz and his pupils, particularly as they dealt with subjects acknowledged to be of great complexity.

Oltmanns' studies have led him to conclusions that may be stated very briefly. There is only one sexual act and that occurs in the carpogonium. The structure derived from the fertilized carpogonium is comparable to the sporophyte generation of higher plants. The plant that bears the sexual organs is the gametophyte. Tetraspores are special forms of reproductive cells that have no fixed place in ontogeny. The fusion of the carpogonium or filaments derived from the carpogonium (sporophytic) with auxiliary cells (gametophytic) is for purposes of nutrition. The sporophyte is dependent upon the gametophyte in a manner analogous to the conditions illustrated by the bryophytes.

Indeed, in certain instances, the sporophyte holds a relationship to the gametophyte closely similar to that of a parasite upon its host. The act of fusion between cells of the sporophyte and the auxiliary cells concerns the cytoplasm alone. In all such instances the sporophytic nuclei remain apart from the nuclei of the gametophyte. They never come together and unite, but rather appear to take up positions somewhat remote from one another. The gametophytic nuclei become less prominent as the cystocarp develops, and finally may be very inconspicuous, or even break down and disappear. The carpospores are developed through the activity of sporophytic nuclei, and these are genetically derived from the fusion nucleus that resulted from the copulation of male and female elements in the carpogonium.

These conclusions of Oltmanns are the results of investigations upon four genera of the red algæ, Dudresnaya, Glœosiphonia, Callithamnion, and Dasya. The descriptions are clear, and the excellent figures will be greatly appreciated by those who know the difficulties of this field of study. The evidence would be convincing, were it not for the absence of certain critical stages of nuclear fusion and nuclear division. Perhaps it is not fair to expect such exactness and so much detail in this first presentation of Oltmanns' theories, and the presumptions are certainly in favor of the correctness of his explanations. However, someone must complete the chain of evidence before we can consider the proof as absolute.

The account of Callithamnion is perhaps the most interesting contribution in the paper, since it concerns a well-known and much studied type. Oltmanns finds that the fertilized carpogonium in *Callithamnion corymbosum* divides into two cells, which extend on each side towards the auxiliary cells. A small cell, cut off from each of these on the side nearest the auxiliary cell, fuses with the latter. A sporophytic nucleus

is thus introduced into both auxiliary cells and divides near the points of entrance. One of these two nuclei passes to the top of each cell, from which region the favella is to develop. The original nucleus (gametophytic) of each auxiliary cell, together with one of the sporophytic nuclei, finally becomes cut off from the developing favella by a wall and takes no further part in the history of the cystocarp. If these observations are confirmed in other species of Callithamnion the fact will be regarded by the writer as one of the most valuable observations that has been published in this field of investigation; for Callithamnion has presented one of the most difficult problems offered to students of the red algæ. Moreover, the physiological conditions there present seem to be duplicated in a number of genera (Spermothamnion, Griffithsia Lejolisia, etc.). A satisfactory explanation for Callithamnion offers the hope that we may finally understand the complicated organization in a number of other forms.

Time alone will determine how generally the theory of Oltmanns may be applied. The instances of detailed observations on the puzzling conditions of this remarkable group of plants are so few, in comparison to the mass of perplexing phenomena presented, that one may well hesitate before considering Oltmanns' views as established. But it appears to the writer that Oltmanns gives us the most reasonable theory yet presented *in extenso*, the most satisfactory working hypothesis for future investigation, and that its stimulus upon research in this group of algæ will be far reaching.—Bradley Moore Davis, *The University of Chicago.*

A NEW SILPHIUM.

In describing a new Silphium as *S. lanceolatum* in the February number of the Botanical Gazette (p. 139) I unaccountably overlooked the fact that Nuttall had used the same specific name in the genus. I therefore propose the name of *Silphium Chickamaugense* for this species.—Wm. M. Canby, *Wilmington, Del.*

OPEN LETTERS.

THE TROPICAL LABORATORY.

UNEXPECTEDLY I have had the opportunity of visiting several of the West Indian islands, and of comparing their botanical possibilities in a superficial way. The readers of the GAZETTE may find of interest a few statements regarding the principal regions, in their bearing upon the tropical biological station which was under consideration.

Jamaica lies six days south of New York, and it requires fifty dollars to pay for the steamer cabin; Trinidad is eight days, and a cabin costs seventy-five dollars.

There can be no question to one who has seen other tropical regions that, while Jamaica has the more beautiful scenery, Trinidad possesses a far more luxurious vegetation. The difference in luxuriance is similar to that between the vegetation of Fiji and Samoa, and does not consist so much in the difference of species as in their development. The valleys and hillsides of Jamaica are covered with the most graceful imaginable patches of bamboo (*B. vulgaris*), standing as monuments to the value of early attempts at plant introduction; the valleys of Trinidad are shaded by gigantic clumps of the same plant which overarch the roads and streams and shade them in the most charming way. Scattered through the gorgeously colored vegetation of the hillsides in Trinidad are innumerable palms, which raise their plumes above the surrounding trees and shrubs; lianas are abundant, and cover the precipitous cliffs like a tattered lace curtain. The streams of Jamaica flow between mountains that are much higher than those of Trinidad; the vegetation of the hillsides is distinctly luxuriant, and, from a scenic standpoint, superior to Trinidad.

Unfortunately for Jamaica the money appropriated for botanical purposes has been expended upon several widely separated stations: the cinchona gardens in the mountains; the old garden at Bath, now abandoned; the Castle gardens, now only cared for by a gardener who spends one day a week upon the ground; and the so-called Hope gardens, within a half hour's ride of Kingston by electric train. The Castleton gardens are well kept up and attractive, but quite small, covering only a few acres, and containing a quite limited number of plants. The fine Cohune palms from Central America, teak, brazilnut trees, a Carnahuba palm from Brazil, Heveas, Castilloa, *Manihot Glaziovii* and other rubber-bearing plants, as well as the gorgeous flowered *Amherstia nobilis*, *Spathodea campanulata*, and the familiar East Indian durian, carambola, and mangosteen fruit trees form some of its principal curiosities.

Three small two-roomed cottages and a small eating house on the hill above the gardens are kept by a native hotel keeper. These furnish the only accommodations possible for a visiting botanist in this quite out-of-the-way, secluded spot. A description of the Jamaica gardens has already been published in the GAZETTE by their able director, Mr. Fawcett. The American student would find it difficult to study at Castleton, as there is no laboratory, and carriage hire to and from Kingston would prove rather expensive. All laboratory material would necessarily be transported from Kingston to this isolated spot, as well as in large part the canned goods upon which he would find it necessary to live.

The well-equipped laboratory of the Hope gardens is one half hour from the town of Kingston. The visitor would be obliged to live in the city of Kingston, and go back and forth on the electric car every day. The laboratory is not equipped for all kinds of botanical work, but is an airy, well kept place, which would form a very pleasant laboratory for a herbarium student, and could easily be fitted up with appliances for microtome or physiological work. The hotel at Kingston at which the visitor would be obliged to put up is quite impossible from an American standpoint, and would go a long way toward giving him several sorts of tropical complaints should he stay long.

Port Antonio, on the north coast of the island, possesses no garden, and the Johns Hopkins laboratory, in which Dr. Humphrey contracted the fever from which he died, consisted of several converted rooms in Captain Baker's excellent American hotel, built upon the substantial profits of the banana trade. Port Antonio is a small town, very picturesquely built on the coast, but affording little of interest in the way of native life and characteristic markets in comparison with Kingston. The roads lead directly through cocoanut plantations or banana fields into the mountains, whence material for study would be easily obtained.

In Kingston, the Jamaica Institute, with its good library of West Indian books, the museum of West Indian natural history, and the laboratory of agricultural chemistry, under the able management of Messrs. Duerden, Condall, and Watts, respectively form a collection of great value to a visitor, enabling him to orient himself quickly in the problems of tropical botany and zoology. So far as official scientists are concerned, Jamaica seems much better supplied than any of the other British West Indian islands. The Agricultural Society, with Mr. Doust in charge, would prove of material assistance to any student interested in agriculture.

The gardens in Trinidad are the largest and best cared for of any it has been my fortune to visit in the West Indies. They are situated beautifully on the open square or "savanna" in the center of the residence portion of the city of Port of Spain. The laboratory is small, but equipped with many of the useful utensils of a working botanist, and a small library of botanical

works. Mr. Hart, the director, whose hospitality I cannot fail to mention in this place, is an indefatigable worker, and would put at the disposition of the visitor every facility in his power. His neatly arranged experimental farm, not far from the gardens, has quite the appearance of a young American experiment station, and his breeding experiments on sugar cane and other plants show his keen interest in the coming problems of tropical agriculture.

The roadways, although few, lead at once into the virgin forest, and with the assistance of a bicycle a collector could easily get together an abundance of material for study. Should he wish to take up the study of any of the many problems which confront the agriculturists of the colony, the utmost would be done to assist him, and pecuniary assistance in the way of compensation for the results of his studies would be a possibility.

The Victoria Institute, with its large comfortable building on the other side of the savanna from the gardens, might prove useful should more room be required than is available in the garden laboratory, or the new building of the experimental farm soon to be constructed.

A comfortable hotel, good shops, a public library, a society of English and Scotch, and a most interesting mixture of East Indians, Chinese, West Indian blacks, and Portuguese make Port of Spain a place full of things, other than botanical, to be studied. I am free to say that, as an average American, Trinidad proved much more to my liking than Jamaica, although the latter has roads all over it, and is more picturesque.

From Trinidad excursions can be made up that as yet little known river, the Orinoco, and to the many small islands lying nearer the mainland.

From the standpoint of a superficial study of the two islands I cannot but express my opinion in favor of Trinidad as the place for a botanic station. Should, however, the lately acquired island of Puerto Rico prove more suitable for a biological station, as seems quite possible, certainly any young student of tropical botany cannot afford to neglect the advantage which Trinidad affords as a place in which to become acquainted with West Indian agriculture and botany.

The recent establishment at Barbados of a Department of Agriculture for the West Indies, with Dr. Morris as commissioner, may in time change the conditions there. At present Barbados has little to offer the student.

The islands of the French West Indies and other of the British West Indies have botanic stations upon them, but, so far as my information goes, are not to be considered in connection with Trinidad or Jamaica.

It would seem to the writer as not at all beyond the pocket of many American botanists to spend a summer vacation in Trinidad, and could they realize the enthusiasm which these tropical plants and animals awaken, they would need no urging.—D. G. FAIRCHILD, on board "Canada," off Savanilla, U. S. of Colombia, February 15, 1899.

CURRENT LITERATURE.

BOOK REVIEWS.

Experimental morphology.

THE second part of Davenport's *Experimental Morphology*, which has been awaited with so much interest, has recently appeared.[1] This part deals with the effect of chemical and physical agents upon growth. It will be remembered that there are to be two parts more, devoted to cell division and development.

The general plan of treatment is the same in this part as in Part I, already reviewed in this journal.[2] Since the phenomena of growth have been more studied in plants, in which they are very prominent and yield themselves much more readily to analysis than in animals, the present part includes a more extensive discussion of plants than the first. This part, therefore, will have, if possible, a greater interest for botanists than the first, though the whole work will be of the greatest service to them.

A chapter is devoted to the effect of each agent which exercises an influence upon the rate or the direction of growth. From the chapter on chemical agents, water is excluded, being given a chapter by itself. Molar agents, gravity, electricity, light, and heat, are discussed in turn, and the part concludes with a chapter on the effect of complex agents on growth, and the general conclusions. Each chapter is followed by a bibliography of the more important papers on the subject treated, a feature of very great value to students.

Because of the wideness of the field traversed, it is impossible that such a work as this should be in the main anything but a compilation of the results of the labors of others, and we are glad enough that some one has had the courage to undertake so vast a task. It would be, therefore, somewhat ungracious to expect, much more to demand, the critical use of the great mass of literature. But most readers will expect a thoroughly digested presentation, and the book may be open to criticism in this direction.

A single illustration of this will suffice to indicate the form such criticism might take. In the discussion of traumatropism of roots, the author cites experiments of Pfeffer which, he says, show that "the identical plasm which is irritated responds, producing the traumatic curvature" (p. 386). But in

[1] DAVENPORT, C. B.—Experimental morphology. Part II. Effect of chemical and physical agents on growth. 8vo. pp. xa–xb, xv–xviii + 281–509. *figs. 75–140.* New York: The Macmillan Company. 1899. $2.00.

[2] BOT. GAZ. **23**: 467. 1897.

discussing geotropic curvatures, he cites other experiments of Pfeffer, from which he concludes that "the curving part of the root can contain none of the originally irritated cells" (p. 396). These views can hardly be reconciled. It seems to be the first induction which is faulty.

The most notable omission is the absence of any discussion of the theories of growth. This could hardly be other than intentional, but surely every reader will expect at least a presentation of the current ideas as to the mechanics of growth.

Some details may now be adverted to in order that readers may be guarded against indiscriminate acceptance of the author's statements and definitions.

It is doubtful whether clearness of ideas is attained by speaking of the cell sap as "living matter." One might with as much justice include the water secreted outside the cell as that secreted within the protoplasm.

Nor can there be any justification for the association of the phenomena of turgor, as in the motor organs of leaves, with those of true growth, under the phrase "transitory growth." Greater clarity of conception and expression is secured by limiting the term growth to the permanent or irreversible changes of form and volume. The dissociation from growth of certain changes (in the interior of spores, etc.) which do not result in increase of volume (the author's sole criterion of growth) is difficult and of doubtful value. In fact, it is impracticable to establish a single criterion for growth.

The account of the causes of twining is quite inadequate, as the author does not seem to be aware of the more recent experiments on the subject, none since Darwin's in 1882 being cited. The conclusion generally accepted today is certainly *not* that "twining is mechanical — depending upon the structure of the stem — rather than responsive" (p. 377).

The general discussion of the mechanics of tropic reactions is certainly very unsatisfactory. This is partly due, of course, to the present want of knowledge, a fact which might well have received more stress than the author gives it. The assumptions that are made are too many and too bold to be of any assistance in clearing up this very difficult subject. For example: the relations of growth and turgor are too uncertain at present to permit the mechanics of phototropism to be explained through the intervention of turgor. It must first be demonstrated that turgor controls growth, and not growth turgor. Again, the separation of the slow reactions from the more rapid ones, and the assumption that the former are due to "differential imbibition" and the latter to "assimilation," while the ones of intermediate rate "are probably due to the combined action of assimilation and imbibition," is not only gratuitous, but absolutely misleading (p. 481). And surely the author does not mean what he says when he suggests that "the tropic agent causes such a change in the molecules of the curving region as to cause them to imbibe water with abnormal activity" (p. 482).

In spite of such minor defects, which are of importance only to the student whose knowledge is not general enough to guard against them, this part, like its predecessor, must take a high rank among the books destined to advance the knowledge of living organisms. This it will do, not only by making more available an immense mass of important data, and pointing out the source of others, but still more effectively by its suggestiveness as to profitable direction for experimentation.—C. R. B.

The principles of agriculture.

THE authors of books written in illustration and aid of agriculture may be roughly grouped into three classes. First, those who, unacquainted with science, are adepts in practice and have faithfully described their own methods, together with the usages of others who have successfully followed some branch of the business of farming; second, those who have written from the standpoint of pure science; and third, those who combine a practical knowledge of agriculture[3] with a thorough knowledge of the sciences with which the art is intimately related and upon which the best practice chiefly depends.

Professor Bailey belongs to the latter class and his qualifications for writing or editing a text-book treating of the "principles of agriculture" are by no means slender.

Will the book edited and largely written by him, meet the needs of those for whom it is designed? Let us consider.

The general arrangement or plan of the book is excellent. It begins with an appropriate introduction, which defines agriculture and its main subdivisions, discusses the personal factors upon which success depends, and shows the relation of the natural sciences to this great industrial art.

The main body of the book is divided into three parts, viz.: The soil; the plant, and crops; the animal and stock. The six chapters into which part one is divided are written by four different men. Part two has three different authors, and part three has four.

Those who have assisted Professor Bailey in the preparation of this work are his colleagues or associates in Cornell University as follows: I. P. Roberts, James Law, H. H. Wing, John W. Spencer, L. A. Clinton, G. W. Cavanaugh, and B. M. Duggar.

In addition to its logical arrangement the book has the merit of being written in language that few can can fail to understand. The use of terms unfamiliar to the general ear has been avoided, and there are few paragraphs which will not be readily and fully understood by the average school boy of fifteen or sixteen years.

[3] BAILEY, L. H., *et al.*: The principles of agriculture. A text-book for schools and rural societies. 12mo. pp. 300. Illustrated. New York: The Macmillan Company. 1899. $1.25.

If the book has any weakness it is that it attempts too much. It presents such a vast array of principles, in so brief or concentrated a form, that there is danger of cloying the appetite, or producing mental dyspepsia. Some of the principles named are axiomatic and it seems scarcely necessary to repeat so much self-evident truth. In some cases non-essentials are emphasized and essentials are passed over slightly. By restricting the number of topics, and elucidating the more important principles, the probability of treating them to the average student's profit would be greatly increased.

A book treating of the principles of agriculture can scarcely be called complete which has nothing to say about exchange and distribution. If farming is a business, the machinery whereby the farmer converts into money, or other values, that portion of his products which is not consumed on his farm, and the principles concerned in such exchange, are nearly as important as those concerned in mere production.

It seldom happens that a book which is the joint product of so many different contributors possesses such a clear, vigorous and attractive style throughout as does this one. Scholarship and training are evident in every chapter.

If this book could be placed in the hands of each earnest young farmer, it could scarcely fail to give him a broader, truer conception of what farming really is, and would teach him that thought and study, observation and reflection are just as essential and serviceable upon the farm as elsewhere.

To all those who are resolved to be good farmers we commend this volume, because no man in this age can be a thoroughly good farmer without the knowledge which can be more easily and rapidly acquired here than elsewhere.—W. R. LAZENBY.

MINOR NOTICES.

THE "NEW EDITION" of Hansen's *Pflanzenphysiologie*, bearing date of 1898, seems to be only a re-issue of that well and favorably known book.[4] It was primarily intended for that large circle of readers who are chiefly interested in some other field of science, but wish to have simple, accurate, and concise information concerning the fundamental facts and principles of plant life. This mission it fulfilled well. It would be wise to have the progress which has been made since 1890 embodied in a thoroughly revised edition. To those who do not already know and use the original edition, we commend it as presenting many points in a clear and interesting fashion, with happy citation of examples.—C. R. B.

THE SATISFACTORY reception which has been given to Russell's *Dairy*

[4] HANSEN, ADOLPH: Pflanzenphysiologie. Die Lebenserscheinung und Lebensbedingungen der Pflanzen. Neue Ausgabe. 8vo. pp. viii + 314. *figs. 160.* Giessen: J. Ricker'sche Buchhandlung. 1898.

Bacteriology[5] has encouraged the author to prepare the fourth edition, which is a thorough revision of the third. The work is divided into three parts; first, the structure, form, physiology and methods of study of bacteria in general; second, the contamination and fermentation of milk, and the proper means of milk preservation; third, the relation of bacteria to milk products, as concerns both their desirable and undesirable effects.

The work is excellent in that it makes practical application of so much of the purely scientific work of bacteriology. It furnishes a further testimony to the mutual relation existing between research and practice. It seems, however, that the book should contain figures of those bacteria found in connection with dairying, which induce not only unfavorable conditions in milk, but also of those which induce diseases of men, since illustrations would better enable students of dairying to identify such organisms when present. It is quite noticeable that so important a work as the *Manual of Bacteriology* by Muir and Ritchie should be omitted from the author's list of works which "contain more or less complete descriptions of the various processes employed in studying bacteriology."

As a text upon dairy bacteriology the book fills a place not approached by any other work, as shown by the fact that it is now used in all the dairy schools of the United States and Canada. In addition to the interest in the book on the part of students in such schools, the subject is of so much importance to all users of milk and its products, and the book is so excellently written that it should be extensively recommended to all as a study in public hygiene. —OTIS W. CALDWELL.

NOTES FOR STUDENTS.

FASCICLES III and IV of the *Fungi Rossiæ Exsiccatæ* contain a number of interesting Uredineæ collected by Mr. Komarov in Mantchuria, and included because the flora is similar to that of some of the Russian provinces. As the plants of that region are so closely related to those of eastern America, it was to be expected that some of our parasitic fungi would occur there. Accordingly we find *Puccinia Waldsteiniæ* Curt.; *P. Haleniæ* Arth. & Holway, hitherto only known from northern Minnesota; a variety of *P. Heucheræ* (Schw.) Diet.; *P. mesomegala* Berk. & Curt.; *Æcidium Sambuci* Schw.; and *Uromyces Lespedezæ* (Schw.) Pk.—E. W. D. H.

THE FEBRUARY number of *Natural Science* is an interesting, if not in all instances a gratifying, one to students of ecology, containing, among other things, papers on the study of plant associations by Robert Smith, mimetic resemblances in animals and plants by Professor Henslow, and bees and the origin of flowers by G. W. Bulman. The first is chiefly interesting because

[5] RUSSELL, H. L.: Outlines of dairy bacteriology. 4th ed. pp. vi + 190. *figs.* 39. The Author, Madison, Wis., 1899.

of an analysis of the earlier treatment of plant formations or associations; Professor Henslow concludes, after an employment of the expressions "mimicry" and "mimetic," which is rather different from that usual with naturalists, that "natural selection is quite uncalled for, and, in fact, has no *raison d'être* in the origin of any structure whatever;" and Mr. Bulman reaches the conclusion that the theory of the origin of flowers by the selective action of insects, "as taught by Darwin, Wallace, Hermann Müller, Sir John Lubbock, and Mr. Grant Allen, is absolutely incompatible with the facts of the mutual relations of insects and flowers."—W. T.

IN A PAPER[6] reviewed in an earlier number of this journal,[7] Oltmanns claimed to have disproved the earlier work of Berthold,[8] according to which, in *Ectocarpus siliculosus*, a quiescent female gamete becomes attached to several male gametes, with which it is said to fuse. Basing his conclusions upon a study of *E. criniger*, Oltmanns claimed that Berthold saw, not fusing gametes, but infusoria capturing and eating the algal zoospores. Berthold replied immmediately,[9] insisting that his preparations were not susceptible of any interpretation other than the one he had already given.

Recent work by Oltmanns[10] upon *E. siliculosus* has led him to abandon his former position, and to confirm the statements of Berthold. He indeed finds infusoria, as before, but he also finds gametes fusing, and described the process quite fully.

Several male gametes become attached to the female by their long anterior cilia; finally one is drawn nearer, and fusion follows. In material collected in the morning this generally occurs before noon, and nuclear fusion is usually completed before night. The fusion of the female with more than one male gamete is very rare, but the author does not tell us of the fate of the second male nucleus when this occurs. The second chromatophore of the normal zygote is said to persist.

We may then say that the Ectocarpaceæ show sexual conditions in all stages of transition from isogamy, through such forms as *Ectocarpus siliculosus*, in which there is hardly more than a physiological differentiation of the gametes, to the distinct heterogamy of *E. secundus*, in which, according to Sauvageau, the two gametes differ considerably in size.

The "neutral" swarm-spores which are almost always associated with the gametes in the plurilocular sporangia, arise secondarily by the failure of sexual fusion, and therefore do not stand in a close phylogenetic relation to the swarm-spores of the unilocular sporangia.—W. D. MERRELL.

[6] Flora **83**: 398–414. 1897.

[7] BOT. GAZ. **24**: 383–384. 1897.

[8] Mittheil. d. zool. Stat. Neapel **2**: 401. 1881.

[9] Flora **83**: 415–425. 1897.

[10] Ueber die Sexualität der Ectocarpeen. Flora **86**: 86–99. 1899.

NEWS.

MR. M. A. CARLETON is on his way back to America after a tour through Russia under the auspices of the U. S. Department of Agriculture.

MM. CASIMIR and Lucien de Candolle have presented to the University of Geneva a bronze bust of Alphonse de Candolle, the work of the sculptor Bovy.

DR. BENGT JÖNSSON, previously docent, has been appointed assistant professor of botany in the University of Lund, in charge of anatomy, physiology, and ecology.

MR. A. A. HELLER, who is collecting in Puerto Rico, reports good success. He finds the roads excellent, making it very easy to reach all parts of the island by using a bicycle.

DR. M. RACIBORSKI has left the Experiment Station for sugar cane in Kagok Tegal and has been appointed to a post at Buitenzorg, in charge of investigations upon tobacco.

MR. B. T. GALLOWAY has returned to Washington, D. C., from an extended visit in California, where he had gone to regain health. He returns much improved, and is able largely to resume his duties as Chief of the Division of Vegetable Physiology and Pathology.

DR. RICHARD WETTSTEIN, Ritter von Westersheim, professor of botany in the German University of Prag, has been called to the professorship of systematic botany in the Imperial University of Vienna as successor to the late Anton Kerner, Ritter von Marilaun.

THE MUSEUM and laboratory building in the New York Botanical Garden is making fair progress toward completion. It is now entirely enclosed, and the partition walls and other rough interior work are mostly finished. The present outlook indicates that it will be ready for occupancy late in the spring. The foundations for the glass houses will be laid when the ground is free from frost.

OUR NOTE in the March number regarding the fire at the University of Geneva, based upon information obtained from *Nature* and the *Gardeners' Chronicle*, was fortunately incorrect. The Delessert herbarium was not housed in University buildings but at some distance, and it is unharmed.

Correspondents inform the *Gardeners' Chronicle* that "the fire broke out in the left wing of the University, and destroyed an apartment in which were some collections, diagrams, etc., relating to the Alpine flora, belonging to Professor Chodat. Some loan collections from foreign herbaria were likewise destroyed, as well as some physical instruments that had belonged to De Saussure."

THE historico-biographical work, entitled *The botanists of Philadelphia and their work*, by Dr. John W. Harshberger, instructor in botany in the University of Pennsylvania, is now ready for the press. It will be printed as soon as sufficient subscriptions have been secured. Philadelphia in colonial days was the scientific and literary center of Amercia and the botanists of Philadelphia did much good and lasting scientific work. The book is a contribution to the history of the rise and development of botany in America; for many of our early botanists of historic importance were Philadelphians. It is to be illustrated by about fifty full page portraits.

WILHELM ENGELMANN, Leipzig, announces that he will begin publishing, in the course of the year, a work by Dr. C. G. De Dalla Torre and Dr. H. Harms, entitled *Genera Siphonogamarum*. It is to present a synopsis of the orders, families, genera and sections of the spermatophytes based upon Engler and Prantl's *Natürliche Pflanzenfamilien*. The important synonymy, references to the basal work, and various other conveniences are promised. Such a book will be a great convenience to systematists, and will be especially useful in arranging herbaria in accordance with a modern system. It will take a place similar to Durand's *Index Phanerogamarum*, which was based upon Bentham and Hooker's *Genera Plantarum*. The work will be issued in ten parts, of about 160 pages each.

THE FIELD WORK in the southern Rocky mountains, carried on in the La Plata region in 1898, by Messrs. Baker, Earle, and Tracy, will this year be extended into the San Juan region, the extreme eastern extension of the Great Basin watershed in southwestern Colorado and northwestern New Mexico. Last year the field work was limited to a month, and the plants were determined and issued under difficulties. However, they included many new phanerogams, while a third of the fungi were new. These sets went to the herbaria of Edinburgh, Kew, Berlin, New York, Washington, Chicago, St. Louis, and others. A full report of the 1898 work by Dr. E. L. Greene and Professor F. S. Earle will soon be issued. This year the field work will continue through the entire season in charge of Mr. C. F. Baker (now at St. Croix Falls, Wis.). A full report of results will be published as for 1898, and issued free to subscribers. If complete sets are not desired, selections may be made by groups or by single specimens.